

Test Wells, Meade and Kaolak Areas, Alaska

EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4
AND ADJACENT AREAS, NORTHERN ALASKA, 1944-53
PART 5, SUBSURFACE GEOLOGY AND ENGINEERING DATA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 305-F

*Prepared and published at the request of and in
cooperation with the U. S. Department of
the Navy, Office of Naval Petroleum and
Oil Shale Reserves*



Test Wells, Meade and Kaolak Areas, Alaska

By FLORENCE RUCKER COLLINS

With Micropaleontology of Meade Test Well 1 and
Kaolak Test Well 1, Northern Alaska

By HARLAN R. BERGQUIST

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EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4 AND ADJACENT AREAS, NORTHERN ALASKA, 1944-53

TEST WELLS, MEADE AND KAOLAK AREAS, ALASKA

By FLORENCE RUCKER COLLINS

ABSTRACT

The Meade and Kaolak test wells were drilled in 1950 and 1951 as part of the petroleum exploration program carried on by the U. S. Navy in Naval Petroleum Reserve No. 4, northern Alaska. The wells tested Cretaceous rocks on anticlines defined by seismograph surveys in the western part of the Arctic coastal plain, in areas hitherto little known geologically. Both were abandoned as dry holes, although Meade test well 1 produced a small amount of gas. Both tests penetrated beds of the Nanushuk group. In Meade test well 1 the Nanushuk group includes both marine and nonmarine sandstone and shale, and some coal. In Kaolak test well 1 the Nanushuk group consists of an almost completely nonmarine sequence which contains abundant coal. The sequence underlying the Nanushuk group in both wells is composed primarily of marine shale assigned to the Topagoruk formation in the Meade well and tentatively so correlated in the Kaolak well.

This report contains lithologic, paleontologic, logistic, and engineering information obtained in drilling the tests; much of the data are presented graphically.]

INTRODUCTION

Between 1944 and 1953 the United States Navy conducted a program of petroleum exploration in Naval Petroleum Reserve No. 4, northern Alaska. As a part of this exploration, Meade test well 1 and Kaolak test well 1 were drilled in 1950 and 1951 in an effort to evaluate petroleum possibilities on structural features in the western part of the Reserve. The resultant geologic and engineering data presented here have been compiled in part from reports made for the Navy by various organizations connected with the work. These include Arctic Contractors, who, under contract to the Navy, drilled core holes and test wells in many parts of the Reserve (see fig. 23); under subcontracts United Geophysical Co., Inc., made seismic and gravity surveys; The Schlumberger Well Surveying Corp. made the

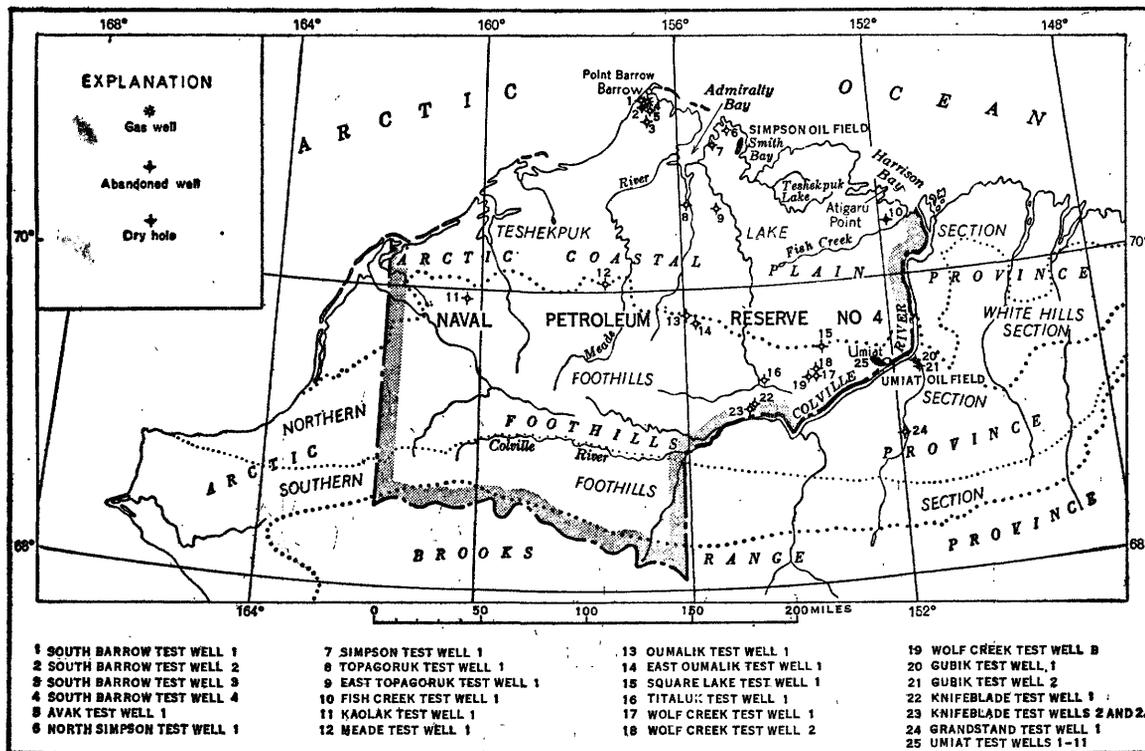


FIGURE 23.—Index map of northern Alaska, showing location of test wells and oil fields.

electric logs; and the United States Geological Survey, as a cooperating agency, studied the geology of the area in the field and laboratory. Descriptions of cores and cuttings, porosity and permeability determinations, and microfossil studies were made in the Survey's laboratory in Fairbanks, Alaska.

Microfossils were identified by Harlan R. Bergquist. The stratigraphic distribution of fossils in the test wells of northern Alaska will be presented by him in another chapter of this series. Megafossils were studied by Ralph W. Imlay. The help of many engineers, geophysicists, and geologists connected with the above organizations is gratefully acknowledged.

MEADE TEST WELL 1

Location: Lat 70°02'30" N., long 157°29'23" W.
Elevation: Ground, 197 feet; Kelly bushing, 211 feet.
Spudded: May 2, 1950.
Completed: August 21, 1950; junked and abandoned.
Total depth: 5,305 feet.

Meade test well 1 was drilled to furnish stratigraphic information and to test the production possibilities of sandstone beds in the Nanushuk group (Cretaceous) on an anticline discovered by seismograph surveys in a comparatively unknown area. Having produced no oil and only a small amount of gas, the hole was abandoned after an unsuccessful fishing operation, after the Nanushuk group had been completely penetrated.

The test hole is about 100 miles south of Barrow, near the southern edge of the Arctic coastal plain, on the low watershed between the north-flowing Meade River and a small tributary from the west. The ground is very gently rolling, with a dendritic drainage pattern interrupted by many lakes and marshy areas. (See fig. 24.) Some of the larger rivers have cutbanks along their channels, but other outcrops are lacking. The tundra-covered ground is permanently frozen to a depth of several hundred feet, except for a 6-inch layer at the surface which thaws each summer.

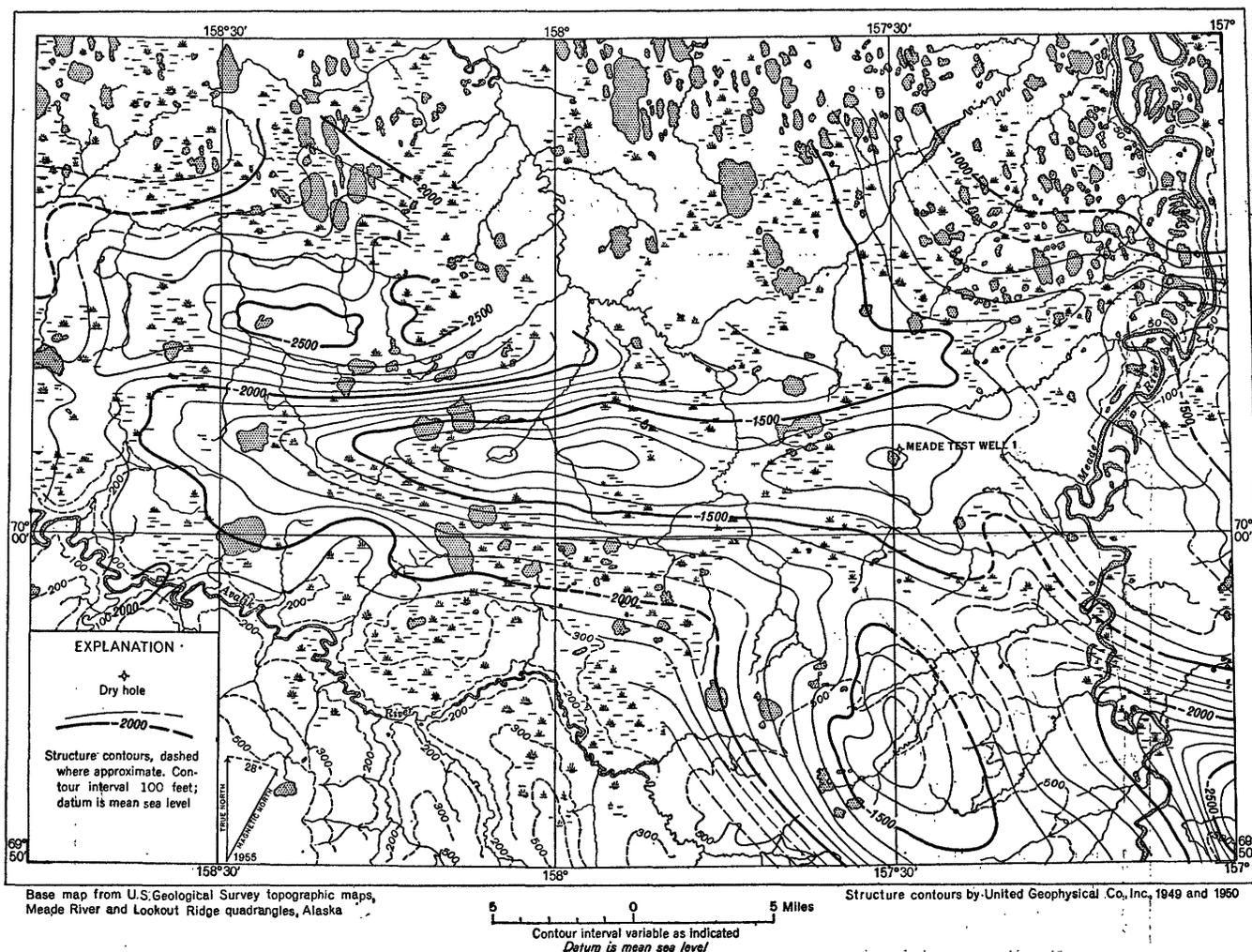


FIGURE 24.—Structure-contour map of the Meade anticline, contoured on a seismic horizon in Cretaceous rocks, and showing the location of Meade test well 1, Alaska.

Seismograph studies by United Geophysical Co., Inc., in 1949 and 1950 show the Meade anticline to have a closure of about 200 feet on a horizon approximately 1,300 feet below sea level (see fig. 24); at this depth the area of closure is 7 miles long and 3 miles wide. The anticline steepens with depth, and on a seismic horizon near the top of the Topagoruk formation at 4,500 feet below sea level, closure over approximately the same area is 500 feet. The anticline is approximately parallel to other subsurface anticlines farther southeast. The regional dip is southwest.

Meade test well 1 is on the southwestern end of a large oval area of very low gravity; the part with the lowest gravity extends northeast 20 miles, as indicated by a United Geophysical Co., Inc., survey in 1950. An aeromagnetic survey of the Reserve by the U. S. Geological Survey in cooperation with the U. S. Navy in 1945 and 1946, revealed two areas of high magnetic intensity 30 miles northeast and 20 miles southeast of the hole that interrupt the southwesterly regional decrease in magnetic intensity of the western part of the Reserve. In addition, a small low-intensity area south of the hole and an equally small area of slightly higher intensity southwest of the hole are present on the regional gradient.

STRATIGRAPHY

The following table gives the depths at which the various stratigraphic units are found.

Formations penetrated in Meade test well 1

Depth (in feet)	Age	Group	Formation and subdivision
14-25	Quaternary		Gubik formation.
25-1, 235	Early Cretaceous	Nanushuk	Chandler formation (Killik tongue).
1, 235-4, 200	Early Cretaceous	do.	Grandstand formation.
4, 200-5, 305	Early Cretaceous		Topagoruk formation.

The Gubik formation (Pleistocene) makes up a thin mantle of unconsolidated silt, sand, and gravel overlying Cretaceous strata. Lenses of ice are common, and a few Foraminifera were recovered.

The Cretaceous rocks include clay shale, sandstone, and coal. The coal is concentrated in the upper part of the sequence; the sandstone, through the central part; and the clay shale, in the lower part; but no sharp lithologic breaks are present. The formation boundaries given are therefore only approximate and are placed within the transition zones.

The nonmarine Killik tongue (Lower Cretaceous) of the Chandler formation, about 1,200 feet thick, is the uppermost part of the Nanushuk group (Lower and Upper Cretaceous) present in this hole. It is composed of medium dark-gray silty clay shale with

interbedded coal, and some siltstone, silty and argillaceous sandstone, and clay ironstone. The coal beds total about a quarter of the rock and are from a few inches to several feet thick. A 30-foot bed was reported by the drillers between 40 and 70 feet; ditch samples suggest the presence of other beds almost as thick, but the greatest thickness verified by coring was about 3 feet.

The top of the underlying Grandstand formation is placed at 1,235 feet, at the top of a thick sandstone. The formation is mostly marine sandstone with some interbedded clay shale, but it also contains many coal beds, especially in the upper 500 feet. The coal beds are less numerous, and most are thinner than those in the Killik tongue of the Chandler, and they are interbedded with strata containing Foraminifera of the marine *Verneuilinoides borealis* assemblage. (See p. 373.) The light-gray sandstone beds are 2-30 feet thick and are very fine to fine grained, commonly argillaceous, and rarely slightly calcareous. The sandstone is composed of subangular grains of clear and white quartz, with some dark rock particles. Porosity ranges from 3 to 19 percent; permeability was measured at less than 2 millidarcys, except for samples at 2,953 feet, which measured 9.5 to 13 millidarcys. Clay shale makes up a large amount of the formation; it is medium dark gray, silty, and noncalcareous, and much of it has carbonized plant fragments or carbonaceous particles on partings. Siltstone, another important constituent of the formation, is medium gray, argillaceous, and micaceous; it also has a few carbonaceous partings. The bottom of the formation, at 4,200 feet, is at the base of the lowest bed of sandstone penetrated in this hole.

The underlying Topagoruk formation (Lower Cretaceous), the oldest rock penetrated by the test, is marine shale which, like the Grandstand formation, contains representatives of the *Verneuilinoides borealis* microfauna. The formation consists, in this test, of 1,105 feet of medium-dark-gray noncalcareous clay shale with some silty laminae. It is slightly carbonaceous, and pyrite particles are present in a few intervals.

DESCRIPTION OF CORES AND CUTTINGS

The descriptions of the rocks penetrated in Meade test well 1 and in Kaolak test well 1 are based on examinations of ditch samples and cores. Depths are measured from the top of the kelly bushing. The material was described dry, and colors were determined by comparison with the Rock Color Chart (Goddard and others, 1948).

Composition as shown on the graphic logs (pls. 21, 22) differs somewhat from that in these descriptions,

because the former is based on an interpretation of the electric log as well as of the ditch samples, some of which are contaminated by cavings from above.

Clay ironstone is a dense, hard, yellowish-gray to grayish-yellow and grayish-orange argillaceous rock with conchoidal fracture; it is sideritic, and usually reacts with cold dilute hydrochloric acid.

The abundance of microfossil specimens mentioned at the beginning of each core description is defined as follows: 1-4 very rare, 5-11 rare, 12-25 common, 26-50 abundant, over 50 very abundant.

Lithologic description

[Where no cores are listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
----	0-14	Kelly bushing to ground level.
----	14-25	No samples available for this part; the drillers reported tundra, silt, sand, gravel, and ice to 25 ft.
----	25-40	No samples were taken; drillers reported 8-ft coal bed at 25 ft, shale to approximately 40 ft. Top of Killik tongue of Chandler formation placed at 25 feet.
----	40-70	Samples from 40 to 70 ft were taken from the cellar and hence are not reliable; in this part, however, they consist of coal fragments with rare sand and gravel, and reflect an unbroken 30-ft coal bed reported by the drillers. Gravel is contamination from surface alluvium; small amount of light-brown siltstone also present. Coal is black, vitreous, bituminous, and has irregular or blocky feature.
----	70-80	Samples contained coal, with small amount of sand and gravel; drillers recorded soft sticky clay shale.
----	80-110	No samples available for this part; well geologist reported soft sticky clay.
----	110-120	Coal, with small amount of soft gray shale.
----	120-130	Clay shale, medium light-gray, soft (slightly bentonitic?); coal; and brownish-gray silty noncalcareous hard clay ironstone.
----	130-140	Sandstone, medium light-gray, very fine-grained, very silty and argillaceous, calcareous, with rare carbonaceous particles. It is composed of subangular clear and white quartz and gray chert. Mica rare; glauconite and pyrite absent.
----	140-150	Coal, and siltstone, medium-light-gray, argillaceous, calcareous, with rare carbonaceous particles.
----	150-160	Clay shale, black, with carbonaceous laminae, and medium-light-gray clay shale, sandstone, and siltstone.
----	160-190	Clay shale with some siltstone and sandstone. Clay ironstone is abundant at 170-180 ft.
----	190-200	Clay shale, medium-gray, slightly calcareous; with rare siltstone, sandstone, and clay ironstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	200-230	Sandstone, very fine-grained, with small amounts of clay shale and clay ironstone.
----	230-260	Coal, with minor interbedded soft, gray clay shale and rare siltstone.
----	260-290	Clay shale, medium-light-gray; siltstone, and sandstone, with clay ironstone concretions; rare coal.
----	290-292	No sample.
1	292-300	Recovered 5 ft: Microfossils absent. 2 ft 4 in., siltstone, light-medium-gray, very calcareous, micaceous, well-indurated. Scattered flakes and laminae of carbonaceous material mark uneven bedding planes; some of these are crossbedded, with dips as high as 15°. Slickensides (dip approximately 15°) present 3 in. above base of siltstone; steeply dipping calcite veinlet 6 in. long occurs immediately above slickensides. 2 ft 8 in., claystone, medium- to medium-dark-gray, calcareous, with subconchoidal fracture; contains fragments of carbonized plants. A 1-in. bed of yellowish-gray clay ironstone present 15 in. below top of claystone.
----	300-310	Clay shale, dark-gray, with small amount of medium-light-gray clay shale and light-gray sandstone.
----	310-330	Siltstone and medium-light-gray clay shale with small amount of coal.
----	330-340	Coal, with rare streaks of gray clay shale.
----	340-350	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, slightly calcareous, composed of subangular to subrounded clear quartz with some white, gray, and tan chert. No mica, glauconite, or pyrite.
----	350-380	Siltstone and gray clay shale with streaks of coal; some ironstone concretions; small amount of black shale.
----	380-440	Coal, with streaks of gray clay shale, and clay ironstone; shows of coal gas reported in the ditch.
----	440-470	Clay shale, medium-gray, clay ironstone, and some siltstone, sandstone, and coal.
----	470-500	Sandstone as above, with streaks of gray clay shale, coal, siltstone, and clay ironstone.
----	500-510	Coal, with sandstone, siltstone, and shale; a show of coal gas in the ditch.
----	510-520	Sandstone, with streaks of gray clay shale, coal, and siltstone.
----	520-540	Clay shale, medium-light-gray, sandstone, siltstone, coal, and clay ironstone.
----	540-560	Coal with streaks of gray clay shale, rare sandstone, and clay ironstone.
----	560-590	Clay shale, medium-light-gray, sandstone, siltstone, with small amount coal and clay ironstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
2	590-601	Recovered 4 ft 6 in.: Microfossils absent. 3 in., clay shale, medium-dark-gray, fissile, noncalcareous, with scattered carbonized plant fragments. Beds lie approximately flat.
		1 ft 4 in., interlaminated coal and black carbonaceous clay shale (beds usually less than 1 mm thick, rarely 5 mm) badly infiltrated with drilling mud.
		8 in., carbonaceous clay shale, medium-dark- to dark-gray, with abundant fragments of carbonized plants; grades into claystone below.
		2 ft 3 in., claystone, medium-dark-gray, slightly silty, with scattered fragments of carbonized plants.
---	601-660	Clay shale, medium-light- to medium-dark gray; sandstone, siltstone, with coal and clay ironstone abundant in upper 40 ft, silty limestone in bottom 20 ft.
---	660-670	Sandstone, with small amount shale and ironstone.
---	670-740	Clay shale, medium-light-gray, with a small amount of siltstone, sandstone, coal, ironstone, and dark-gray shale.
---	740-780	Clay shale, medium-light- to medium-dark-gray, noncalcareous; coal, small amount siltstone, and clay ironstone.
---	780-810	Coal, with rare clay ironstone.
---	810-890	Clay shale, medium-light- to dark-gray, with slickensides on some fragments; coal abundant at 830, 850, and 870-880 ft; clay ironstone increases with depth.
3	890-900	Recovered 6 ft: Microfossils absent. 1 ft 8 in., coal, interlaminated with dark-gray carbonaceous clay shale. Grades into unit below.
		11 in., clay shale, dark-olive-gray, fissile, noncalcareous, with fragments of carbonized plants scattered throughout. Beds lie approximately flat.
		8 in., clay shale, olive-gray, noncalcareous, hard, with rare flakes of carbonized plants.
		1 ft 3 in., siltstone, light-gray, argillaceous, noncalcareous, with scattered flakes of carbonaceous material and mica. Rare sandy micaceous streaks (sand is very fine grained, angular to subangular, white and clear quartz); clay laminae also present.
		1 ft, claystone, medium-gray, slightly silty, noncalcareous, slightly micaceous. A few fragments of carbonized plants present.
		6 in., siltstone as above.
---	900-910	Coal, with some gray clay shale and rare sandstone.
---	910-940	Clay shale, medium-light- to medium-dark-gray; coal.

Lithologic description—Continued

Core	Depth (feet)	Remarks
---	940-970	Coal, with some clay shale and rare clay ironstone.
---	970-1, 010	Interbedded clay shale and coal, scattered fragments of clay ironstone.
---	1, 010-1, 030	Coal with streaks of medium-gray clay shale.
---	1, 030-1, 100	Clay shale, gray, coal, and carbonaceous siltstone; shale increases with depth.
---	1, 100-1, 110	Clay shale, medium- to medium-dark-gray, noncalcareous; very slightly silty in part.
---	1, 110-1, 120	Coal with streaks of clay shale.
---	1, 120-1, 140	Clay shale, coal, and siltstone.
---	1, 140-1, 160	Coal.
---	1, 160-1, 190	Clay shale, medium-gray, slightly silty in part; thin streaks of coal in upper 20 ft.
4	1, 190-1, 197	Recovered 3 ft 10 in.: Microfossils absent. Siltstone, medium-light-gray, argillaceous, micaceous, calcareous, with irregular laminae, thin beds, and small lenses of medium-dark-gray micaceous clay. Clay totals less than 10 percent of recovered core. A ½-in. bed of grayish-yellow clay ironstone, gradational to the medium-gray clay above and below, occurs 2 in. above base of core.
---	1, 197-1, 235	Clay shale, medium-gray, slightly silty in part.
---	1, 235-1, 240	Sandstone and clay shale, slightly silty, with clay ironstone. Top of Grandstand formation is placed at 1,235 ft.
---	1, 240-1, 250	Sandstone, light-yellowish-gray, very fine- to fine-grained, slightly calcareous, with subangular to subrounded grains of clear and white quartz and some yellow and orange chert. Clay shale and coal also present.
---	1, 250-1, 260	Coal, with rare sandstone.
---	1, 260-1, 280	Clay shale, sandstone, and coal.
---	1, 280-1, 290	Coal, with rare clay shale.
---	1, 290-1, 317	Clay shale, medium- to medium-dark-gray, slightly calcareous in part, with streaks of siltstone and coal.
---	1, 317-1, 340	Sandstone, light-gray, very fine- to fine-grained, friable, noncalcareous.
---	1, 340-1, 450	Clay shale as above, and black fissile clay shale; small amount siltstone, sandstone, coal; rare pyrite below 1,380 ft.
---	1, 450-1, 470	Sandstone as above, and medium- to medium-dark-gray noncalcareous clay shale; rare pyrite.
---	1, 470-1, 490	Clay shale, as above, with slight amount of sandstone and coal; pyrite rare.
5	1, 490-1, 500	Recovered 10 ft: Microfossils absent. 1 ft 2 in., clay shale, olive-gray, silty, noncalcareous, with patches and irregular laminae of medium-gray clay shale and abundant carbonized plant fragments marking irregular bedding planes.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		8 ft 10 in., claystone, medium-gray, slightly silty, micaceous, noncalcareous, with some fragments of carbonized plants. Mica and silt decrease downward and are absent at lower end of core. Cleavage changes from irregular to subconchoidal with increasing depth.
----	1, 500-1, 530	Clay shale as in core 5.
----	1, 530-1, 540	Coal.
----	1, 540-1, 590	Clay shale, as above, with some coal and clay ironstone, and small amount of sandstone in lower 10 ft. Rare pyrite.
----	1, 590-1, 610	Coal, with some clay shale as above.
----	1, 610-1, 620	Clay shale and coal with rare siltstone.
----	1, 620-1, 640	Coal, interbedded with clay shale; rare siltstone and sandstone.
----	1, 640-1, 730	Clay shale, medium- to medium-dark-gray, and coal, with small amount clay ironstone, sandstone, and siltstone.
----	1, 730-1, 790	Clay shale, with small amount coal, sandstone, and siltstone.
6	1, 790-1, 800	Recovered 10 ft: Microfossils very rare. 6 in., clay shale, medium-dark- to dark-gray, slightly silty in part, noncalcareous; subconchoidal to poor shaly cleavage; some carbonized fragmental plant remains on partings. Grades into unit below. 4 in., siltstone, light- to medium-light-gray, very argillaceous, calcareous, with irregular laminae and partings of micaceous carbonaceous medium-dark-gray clay. Grades into unit below. 1 ft 1 in., clay shale as above. This, and all beds listed below in this core, have gradational contacts. 4 in., siltstone as above. 1 ft 9 in., clay shale as above. 3 ft, siltstone as above, but containing sandy streaks. 9 in., clay shale as above. 3 in., siltstone as above. 6 in., clay shale as above. 6 in., siltstone as above. 1 ft, clay shale as above; a 1-in. bed of yellowish-gray clay ironstone 3 in. above base of core contains a worn pelecypod shell.
----	1, 800-1, 810	Sandstone, medium-light-gray, very fine- to fine-grained, noncalcareous, with small amount of siltstone and shale.
----	1, 810-1, 955	Clay shale, with small amount of coal, clay ironstone, siltstone, and sandstone. Pyrite rare.
----	1, 955-1, 970	Sandstone, light-gray, very fine-grained, very slightly calcareous; composed of white and clear subangular quartz grains, with streaks of carbonaceous material; no mica, glauconite, or pyrite.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	1, 970-2, 000	Clay shale, with some sandstone, coal, and siltstone.
----	2, 000-2, 030	Sandstone as above, with rare streaks clay shale.
----	2, 030-2, 050	Sandstone with clay shale.
----	2, 050-2, 065	Clay shale, medium- to medium-dark-gray, with small amount sandstone and coal.
7	2, 065-2, 075	Recovered 10 ft: Microfossils very rare. 6 in., siltstone, light-gray, noncalcareous, with scattered carbonaceous micaceous laminae. Dip 2° or less. 9 ft 6 in., clay shale, medium-dark-gray, with thin beds (1 in. thick), laminae, and a few lenses of medium- to medium-light-gray silty clay shale and siltstone. Bedding commonly regular; below 2,074 ft, however, it is interrupted in some places by irregular lenses or fragments (intraformational conglomerate?) of siltstone in the shale. Beds lie approximately flat.
----	2, 075-2, 085	Sandstone and clay shale.
----	2, 085-2, 130	Clay shale, medium-dark-gray, and black fissile clay shale, with streaks of sandstone and rare coal.
----	2, 130-2, 170	Clay shale, medium-dark-gray; medium-gray siltstone, increasing with depth; rare sandstone.
----	2, 170-2, 180	Sandstone, medium-light-gray, very fine- to fine-grained, slightly calcareous; small amount of clay shale.
----	2, 180-2, 220	Sandstone, with some shale, medium dark-gray.
----	2, 220-2, 365	Clay shale, medium-dark-gray, interbedded with medium-gray siltstone and medium-light-gray sandstone. Coal is very rare.
8	2, 365-2, 375	Recovered 10 ft: Charophytes common. 6 ft 6 in., claystone, medium-dark- to dark-gray, with irregular to subconchoidal cleavage. Two large (2 and 3 in. in diameter) yellowish-gray clay ironstone nodules occur at 2,368 and 2,369 ft. Grades into unit below. 3 ft 6 in., clay shale, medium-dark-gray, with laminae and thin beds (three-fourths inch thick or less) of medium-gray silty calcareous clay shale comprising about 15 percent of the rock. A one-eighth inch bed of clay ironstone occurs at 2,373 ft, and a one-fourth inch bed of clay ironstone at 2,374 ft. Slightly carbonaceous, very micaceous partings present throughout. Bedding at 2,373 ft distorted, probably by contemporaneous deformation; beds above and below lie approximately flat.
----	2, 375-2, 430	Clay shale, medium-dark-gray, with siltstone and sandstone; some thin beds of coal.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	2, 430-2, 438	Sandstone with some shale and siltstone.
9	2, 438-2, 445	Recovered 2 ft 10 in.: Microfossils very rare. Sandstone, light-gray, fine- to medium-grained, poorly sorted, very slightly calcareous, friable, predominantly of subangular, clear to milky quartz grains with admixture of dark grains. Entire recovery consisted of small aggregates of sand grains.
-----	2, 445-2, 590	Clay shale with thin beds of sandstone and siltstone. Sandstone contains fine carbonaceous laminae.
-----	2, 590-2, 600	Sandstone as in core 9.
-----	2, 600-2, 689	Clay shale with thin streaks of sandstone and siltstone; rare coal.
10	2, 689-2, 698	Recovered 6 in.: Microfossils absent. Sandstone, as in core 9.
11	2, 698-2, 708	Recovered 1 ft: Microfossils absent. Sandstone, as above, becoming finer and less friable with depth.
-----	2, 708-2, 715	Sandstone as in cores 10 and 11.
-----	2, 715-2, 815	Clay shale, medium-dark-gray, with streaks of siltstone and sandstone as above.
-----	2, 815-2, 820	Sandstone as in core 11.
-----	2, 820-2, 949	Clay shale, medium-dark-gray, with siltstone streaks.
12	2, 949-2, 969	Recovered 19 ft: Microfossils absent. 2 ft, silty clay shale, medium-dark-gray, noncalcareous, finely micaceous, pyritic, hard. 2 in., sandstone, light-gray, fine-grained, subangular, poorly sorted, noncalcareous. 6 in., clay shale, silty, as above. 3 ft 6 in., sandstone, light-gray, fine- to medium-grained, poorly sorted, noncalcareous, moderately hard, subangular grains. Thin laminae of carbonaceous material interbedded at intervals of one-fourth inch or less. Irregular lenticles of carbonaceous siltstone present. Bedding flat. At 2,953 ft effective porosity and air permeability parallel to bedding 19.2 percent and 13.48 millidarcys; normal to bedding 13.7 percent and 9.54 millidarcys, respectively. Light-straw-colored cut, and pale-yellow-green film residue noted in sample from same depth. Content of carbonate minerals at 2,953 ft is 3.93 percent. 7 ft 6 in., sandstone, light-gray, very fine-grained, noncalcareous, dense; predominately quartz, interbedded with thin carbonaceous siltstone laminae so closely spaced as to simulate lines drawn by a fine pen. Many sedimentary structures such as crossbed-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		ding, ripple marks, and "soft rock" flowage are clearly outlined by the carbonaceous laminae. Bedding is flat.
		7 in., silty clay shale, medium-dark-gray, with hackly cleavage; rare fine sand grains scattered throughout.
		4 ft 9 in., sandstone, light-gray, fine- to medium-grained, slightly calcareous, poorly sorted, hard, massive, with subangular grains, and rare carbonaceous laminae. At 2,967 ft effective porosity and air permeability parallel to bedding 7.76 percent and 1.25 millidarcys, respectively; normal to bedding porosity 7.68 percent and rock is impermeable. Content of carbonate minerals 13.4 percent; no cut obtained with CCl ₄ .
13	2, 969-2, 977	Recovered 1 ft 3 in.: Microfossils absent. Sandstone, as above, but with more carbonaceous material. One lamina (one-eighth inch thick) of coal and pyrite. A sample parallel to the bedding had an effective porosity of 5.99 percent; one normal to bedding had 7.02 percent porosity, and both were impermeable. Content of carbonate minerals 8.6 percent. Pale-yellow cut noted in CCl ₄ , with a light-green greasy film as residue.
-----	2, 977-3, 010	Clay shale with some siltstone, and sandstone.
-----	3, 010-3, 020	Sandstone as in core 13, with rare siltstone and shale.
-----	3, 020-3, 050	Clay shale with rare sandstone.
-----	3, 050-3, 060	Clay shale and siltstone, with some sandstone.
-----	3, 060-3, 200	Clay shale, with scattered thin beds of siltstone and sandstone; echinoid spine at 3,100 ft.
-----	3, 200-3, 251	Clay shale with thin sandstone and siltstone beds.
14	3, 251-3, 256	Recovered 1 ft 6 in.: Microfossils absent. Clay shale, dark-olive-gray, slight satinsheen, finely micaceous, hard; breaks irregularly along bedding planes which dip 14°.
15	3, 256-3, 261	Recovered 5 ft: Microfossils common. Clay shale, as above, beds dip 5°-7°; at 3,257 ft two thin (one-eighth inch and one-sixteenth inch) bands of sand grains present in shale matrix—probably fracture fillings.
-----	3, 261-3, 345	Clay shale, medium-dark-gray, noncalcareous, very slightly micaceous.
-----	3, 345-3, 350	Sandstone, light-yellowish-gray, very fine- to fine-grained, highly calcareous, with rare carbonaceous partings.
-----	3, 350-3, 385	Clay shale as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	3, 385-3, 410	Sandstone as above, with some shale in lower 20 ft.
----	3, 410-3, 450	Clay shale, with some interbedded sandstone and siltstone.
----	3, 450-3, 550	Clay shale, with small amount of sandstone and siltstone; sandstone increases with depth.
16	3, 550-3, 555	Recovered 5 ft: Microfossils very rare. Clay shale, medium-dark-gray, finely micaceous, very slightly calcareous; beds dip 5°-10°.
17	3, 555-3, 560	Recovered 4 ft: Microfossils absent. Clay shale, as above.
----	3, 560-3, 610	Clay shale as in cores 16 and 17; rare pyrite.
----	3, 610-3, 620	Sandstone with interbedded shale.
----	3, 620-3, 630	Clay shale as in core 16.
----	3, 630-3, 680	Clay shale with small amount of siltstone; rare pyrite.
----	3, 680-3, 690	Clay shale with interbedded siltstone and some sandstone.
----	3, 690-3, 825	Clay shale, with beds of siltstone at 3,720, 3,740, and 3,755-3,765 ft; rare pyrite.
18	3, 825-3, 830	Recovered 5 ft: Microfossils common. 2 ft 3 in., sandstone, light-gray, very fine-grained, predominantly quartz, faintly calcareous, hard; upper 2 ft badly broken and mixed with drilling mud. 2 ft 9 in., clay shale, medium-dark-gray, finely micaceous; silty partings, thin laminae, and lenticles (one-eighth in. thick or less) of light-gray siltstone. Ripple marks and small-scale cross-bedding present. Beds dip 5°.
19	3, 830-3, 835	Recovered 8 in.: Microfossils common. Clay shale, as above, but without silty partings and laminae.
----	3, 835-4, 114	Clay shale, with thin sandstone and siltstone beds at 3,835-3,840, 3,860, 3,930, 3,940, 3,980-3,990, 4,060, and 4,080 ft. Pyrite very rare.
20	4, 114-4, 119	Recovered 4 ft: Not sampled for microfossils. Sandstone, light-gray, fine-grained, argillaceous, very slightly calcareous, hard; breaks along bedding planes; beds range from ½ to 2 in. in thickness. Beds nearly flat.
21	4, 119-4, 124	Recovered 4 ft: Not sampled for microfossils. Sandstone as above, but becoming more massive and more calcareous with depth. At 4,123 ft effective porosity parallel to bedding 3.14 percent; air permeability 1.3 millidarcys; content of carbonate minerals 31.05 percent.
22	4, 124-4, 129	Recovered 5 ft: Not sampled for microfossils. Sandstone, as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
23	4, 129-4, 134	Recovered 5 ft: Not sampled for microfossils. Sandstone, as in core 21, but becoming somewhat thinner bedded. At 4,130 ft, effective porosity and air permeability parallel to bedding 5.9 percent and 1.36 millidarcys; content of carbonate minerals 10.55 percent. At 4,133 ft, porosity parallel to bedding 9.35 percent; rock is impermeable; content of carbonate minerals 11.1 percent.
24	4, 134-4, 140	Recovered 6 ft: Microfossils absent. 2 in., sandstone, as above. 5 ft 10 in., interbedded light-gray siltstone and medium-dark-gray micaceous clay shale and silty clay shale. Very thin laminae common, but some clay shale beds are 2-3 in. thick. Crossbedding, ripple marks, and crack fillings common and well defined. Beds dip approximately 5°.
25	4, 140-4, 145	Recovered 5 ft: Microfossils absent. Clay shale and siltstone as above.
26	4, 145-4, 150	Recovered 5 ft: Microfossils absent. Clay shale and siltstone in core 24, but with less siltstone.
27	4, 150-4, 160	Recovered 10 ft: Microfossils absent. Clay shale, in core 24, with some silty beds. Beds dip 14° at 4,152 ft. From 4,152 to 4,153 ft well-developed slickensides in a badly fractured zone dip 10°. Dip decreases in lower 5 ft of core, and amount of siltstone diminishes.
28	4, 160-4, 167	Recovered 3 ft 8 in.: Microfossils absent. Interbedded clay shale and siltstone as in core 24.
29	4, 167-4, 174	Recovered 7 ft: Microfossils absent. Clay shale, and silty clay shale, as in core 24. Siltstone laminae increase with depth.
30	4, 174-4, 184	Recovered 10 ft: Microfossils absent. 10 in., clay shale and silt laminae, as in core 24. 2 ft, sandstone, light-gray (salt-and-pepper), fine-grained, very slightly calcareous, hard, tight. A 1-in. bed of clay shale present at 4,175½ ft. 1 ft 4 in., clay shale and siltstone, as above. 10 in., chips of sandstone, as above, mixed with drilling mud. 3 ft 6 in., clay shale, as above. 1 ft, sandstone, as above, but breaks into thin (one-fourth inch) "poker chips." Faint odor of oil. 6 in., clay shale and siltstone, as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	4, 184-4, 200	Clay shale, with rare interbedded sandstone and siltstone in the upper part. Pyrite rare.
----	4, 200-4, 457	Clay shale, with rare thin beds and laminae of siltstone. Rare pyrite below 4,270 ft. Top of Topagoruk formation placed at approximately 4,200 ft.
31	4, 457-4, 463	Recovered 2 ft 4 in.: Microfossils very rare. Clay shale, medium-dark-gray, finely micaceous, noncalcareous. Breaks with irregular fracture. Beds dip 3° or less.
----	4, 463-4, 770	Clay shale as in core 31; silty laminae at 4,710-4,720 ft. Rare pyrite from 4,560-4,720 ft.
32	4, 770-4, 778	Recovered 2 ft 6 in.: Microfossils absent. Clay shale, medium-dark-gray, slightly micaceous, slightly carbonaceous, noncalcareous. Evenly interbedded laminae; thin beds vary slightly in color (from medium dark to dark gray) and silt content (nonsilty to slightly silty). Dip 5° or less.
----	4, 778-5, 048	Clay shale as in core 32, with silty laminae at 4,820, 4,860, 4,880, and 4,930 ft.
33	5, 048-5, 058	Recovered 1 ft 6 in.: Microfossils common. Clay shale as above.
----	5, 058-5, 300	Clay shale as in core 32.
34	5, 300-5, 305	Recovered 3 ft 3 in.: Microfossils absent. Clay shale, medium-dark-gray, very slightly silty, noncalcareous, with some thin beds of dark-gray clay shale and medium-gray silty shale. Poor "poker-chip" cleavage. Dip 6°.

CORE ANALYSES

The effective porosity and air permeability of samples from Meade test well 1, shown in the following table, were determined by the Barnes method, and by the use of a permeameter constructed to meet the general requirements described in American Petroleum Institute Code No. 27, second edition, April, 1942.

Effective porosity, air permeability, and content of carbonate minerals of core samples from Meade test well 1

Depth ¹ (feet)	Effective porosity (percent)	Air permeability (millidarcys)	Content of carbonate minerals (percent by weight)
2,953P	19.2	13.48	---
2,953N	13.7	9.54	3.93
2,967P	7.76	1.23	---
2,967N	7.68	0	13.4
2,966-2,977P	5.99	0	---
2,966-2,977N	7.02	0	8.6
4,123P	3.14	1.30	31.05
4,130P	5.93	1.36	10.55
4,133P	9.35	0	11.11

¹ P=Plug cut parallel to the bedding; N=plug cut normal to the bedding.

HEAVY-MINERAL ANALYSIS

Heavy-mineral samples prepared in the Fairbanks laboratory were analyzed by Robert H. Morris, who compiled the heavy-mineral chart (fig. 25). Sandstone samples were disaggregated and treated with dilute hydrochloric acid to remove the carbonates. The disaggregate was sieved, and the material passing the 80-mesh and retained on the 235-mesh screen was separated in bromoform (sp gr 2.7) and methylene iodide (sp gr 3.0) into light, medium, and heavy fractions. Slides of the heavy fractions (sp. gr. 3.0 or greater) were prepared with canada balsam or aroclor. Two heavy-mineral zones are recognized in Meade test well 1: the euhedral zircon zone, in samples from 2,950 to 2,970 feet, and the zoned zircon zone, represented by one sample from 4,120 feet.

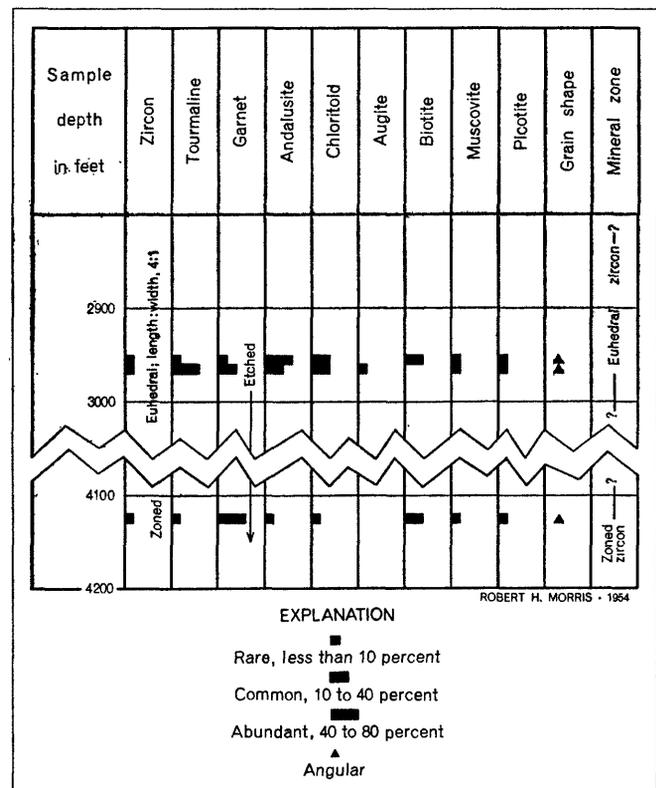


FIGURE 25.—Relative abundance of heavy minerals, Meade test well 1, Alaska.

OIL AND GAS

OIL AND GAS SHOWS

Only a few very faint shows of oil and gas were found during drilling, except for some gas associated with the coal beds. They included shows from two sandstone beds between 2,949 and 2,969 feet, which had a fleeting odor, very pale cut, and no stain; and from a 3-inch bed of sandstone at 4,134 feet that had a fair odor, straw-colored cut, and good fluorescence, as noted by the Arctic Contractors' petroleum engineer. A slight

amount of gas, but not enough to register on the gas detector, was observed at 4,134 to 4,184 feet. Cores were examined in the Fairbanks laboratory one to several days after being shipped from the well, depending on the availability of air transportation. The sandstone was crushed to approximately single-grain-size particles, carbon tetrachloride was added, and the mixture shaken. Any color appearing in the carbon tetrachloride after settling and filtering was described as the cut; the residue was any material left in the evaporating dish after the carbon tetrachloride had evaporated. The consistency of the residue ranged from a greasy film to an oily liquid. An indication of oil at 2,953 feet consisted of a light straw-colored cut and pale-yellowish-green greasy residual film. At 4,183 feet a faint odor of oil was noted in a 1-foot sandstone bed, but no cut or residue was obtained.

FORMATION TESTS

The first formation test was made when the hole was 4,184 feet deep. A Johnston formation tester was set with the packer at 4,116 feet, with 10 feet of perforated pipe below it. The tester was open 1 hour, and a weak steady blow was noted; 50 feet of slightly gassy drilling fluid was recovered. Two more formation tests were made after the hole had been plugged to 3,038 feet. In these tests packers were set at 2,949 and 2,955 feet, respectively, with 10 feet of perforated pipe with enough drill pipe below it to extend from the packer to the top of the plug. The packer failed to hold, in both cases, and no tests were made.

The tester was then removed, and the hole bailed down. When the fluid level reached 700 feet, gas began to flow from the casing, and the fluid could not be lowered farther. The control gates jammed, and the flow was killed with mud in order to make repairs. The fluid was bailed down again, but could not be lowered beyond 650 feet. A critical flow prover with a $\frac{1}{4}$ -inch orifice measured a pressure of 74 psi and a volume of 124,500 cubic feet at a temperature of 74° F. With a $\frac{1}{2}$ -inch orifice, the pressure was 39 psi, the volume 301,000 cubic feet, and the temperature 57° F. The fluid level after testing was 225 feet. The fluid below that depth was gas cut at 1,300 and 1,350 feet and contained 200 ppm chlorides between 1,300 and 3,000 feet, except at 1,990 and 2,100 feet where it contained 600 ppm of chlorides. After the fluid was slowly lowered to 540 feet by bailing, the well was closed in, and the pressure built up to 260 psi in 45 minutes.

A second test with a critical flow prover registered a flow of 718,000 cubic feet per day with a $\frac{1}{2}$ -inch orifice, a pressure of 110 psi, and a temperature of 42°F. With a $\frac{3}{4}$ -inch orifice, the flow was 1,090,000 cubic feet per

day with 70 psi at 42°F; and with a 1-inch orifice, it was 1,132,000 cubic feet with 35 psi at 38°F.

After the 7-inch casing was set at 2,785 feet, a drill stem test was made to make sure the water was shut off. The packer on the drill pipe was set at 2,556 feet with the bottom of the tail pipe at 2,577 feet, 17 feet below the depth at which 4 perforations had been made in the casing by a gun perforator. After a slight blow for 1 minute, drilling fluid rose 450 feet during the 30-minute test.

Twelve holes were then shot between 2,690 and 2,696 feet, and another test was attempted, but the packer, set at 2,652 feet, did not hold. It failed again when it was set at 2,679 feet on a second attempt to test the perforations. A third try, with the packer at 2,494 feet, had a strong blow for 10 minutes which then decreased to a faint blow. Swabbing caused the gas to flow intermittently.

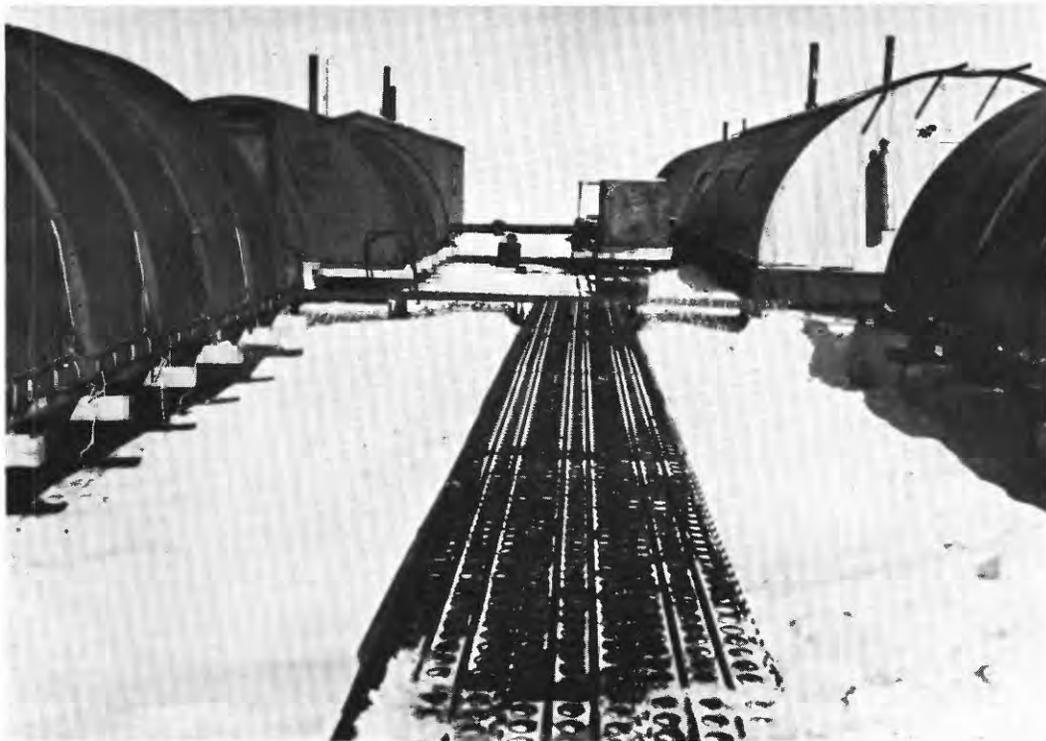
LOGISTICS

Material was brought to the site of Meade test well 1 by tractor train and airplane from the base camp at Barrow; the train hauled 2,500 tons overland before the snow melted, and the airplane brought 100 tons, including perishable goods, personnel, and special equipment or supplies. Small airplanes landed on a nearby lake in summer, and a C-47 with ski-wheels landed on the snow-covered lake ice in winter. A small amount of material was also delivered by LVT.

Personnel.—The petroleum engineer assumed the duties of the drilling foreman during the last 2 months of drilling; prior to that time two men were employed. A geologist was also at the site during drilling. Besides the rig crew of 2 drillers, 2 derrickmen, 6 floormen, 2 firemen, 2 heavy-duty-equipment mechanics, and 1 oiler, 5 other permanent employees were stationed at the site: 2 cooks, 2 cook's helpers, and 1 warehouseman-storekeeper. A temporary personnel comprising such workers as carpenters, laborers, electricians, cementer, and Schlumberger operator came from Barrow as they were needed.

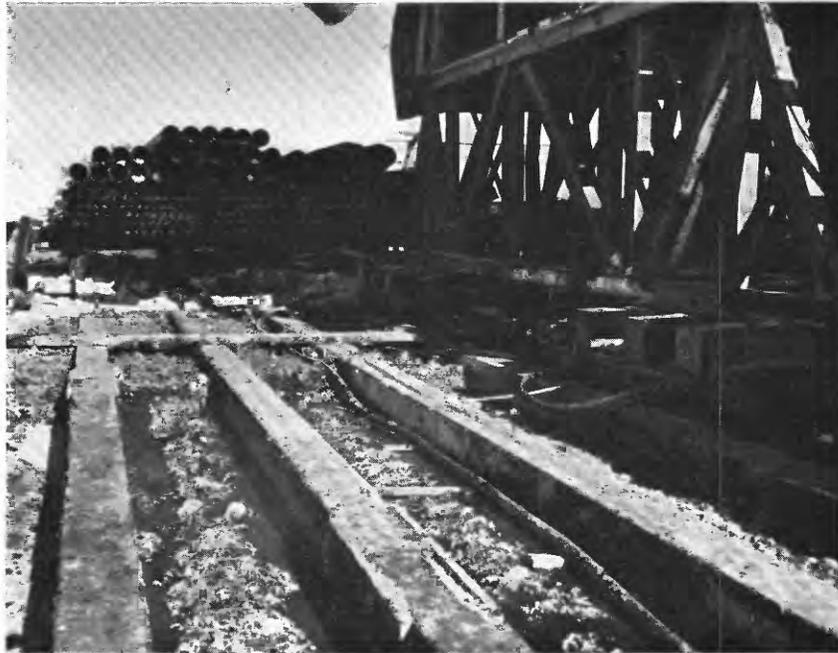
Housing.—Seven jamesway huts (similar in shape but smaller than quonset huts and made of canvas over a metal frame) and a wanigan (a small 1-room building which lacks a stationary foundation, and is often mounted on skids or runners to facilitate moving) were used for sleeping. (See pl. 23.) Another jamesway hut and a quonset hut were used for storage and as a warehouse, respectively; a second quonset served as galley and messhall. Other wanigans housed the boiler, geological office, machine shop, Schlumberger office, generator, utilities, lavatory, and cement.

Vehicles and heavy equipment.—Several vehicles were kept at the site for local use—2 weasels (military fully



THE CAMP AT MEADE TEST WELL 1

Two jamesway huts are on the left; a wanigan is in back of them; on the extreme right is another jamesway hut, with the messhall quonset in the rear. The metal walkways are supported a foot or more above the ground by pipes driven into the frozen soil.



A. MEADE TEST WELL 1



B. KAOLAK TEST WELL 1

RIG FOUNDATIONS

A. The timbers shown here were to support the cementing pump; the steel substructure of the main rig, supported by similar timbers, is on the right; the pipe rack is in the background. B. The piling is supported by 12- by 12-inch timbers capped by a floor of heavy planking.

tracked vehicles), a D8 Caterpillar tractor, a D6 Caterpillar tractor with blades, a Northwest series 5 crane, and a small TD-9 crane (cherry-picker). The list below includes items of heavy equipment used by Arctic Contractors during the drilling:

- 1..Ideco 122-foot derrick.
- 1..Ideco crown block.
- 1..National 50 drawworks, powered by two Caterpillar D13000 engines.
- 1..Ideal rotary table.
- 1..Ideco 200-ton traveling block with four 30-in. sheaves.
- 1..National type D swivel.
- 1..Bryon-Jackson hook no. 4125.
- 1..Kewanee 32-hp boiler, no. 578.
- 1..Gardner-Denver 7¼- by 10-in. pump, powered by a Caterpillar D13000 engine.
- 1..National C-250 7¼ x 15-in. pump, powered by a General Motors quad diesel engine.
- 1..Marlow 4-in. pump.
- 2..Mud tanks, 8 by 24 by 4 ft, made in the Barrow shop.

Fuel, lubricant, and water consumption.—Approximately 52,200 barrels of diesel fuel, 3,378 gallons of gasoline, 2,690 gallons of lubricating oil, 450 pounds of grease, and 415 pounds of thread lubricant were used during drilling. Water added to the mud and used for other purposes totaled 842,500 gallons.

DRILLING OPERATIONS

The derrick and drawworks were mounted on a steel substructure which was set on a foundation of 12- by 12-inch timbers in tundra moss (pl. 24A). One-inch pipes were cleated to the under side of the timbers, and a refrigerant, diesel oil cooled by an 0.42-ton mechanical refrigeration unit, was circulated through them in four circuits. This served to keep the ground beneath the rig from thawing, and no settling of the rig was noticeable while the system was in operation from May 8 to July 9, 1950.

DRILLING NOTES

The following summary of drilling operations was recorded by C. S. Roberts, petroleum engineer.

Notes from drill records

<i>Depth (feet)</i>	<i>Remarks</i>
111.....	Set 88 feet of 16¼-in. ⅝-in. thick welded plate 60-lb slip-joint Western Pipe and Steel surface casing (jacketed between 38 and 66 ft with 23⅝-in. casing) at 92 ft and cemented with 97 sacks of Cal-Seal.
1,038.....	Mud came up around the 16¼-in. surface pipe into cellar. Mixture of 18 sacks of Cal-Seal and 20 sacks of Oilwell cement placed around top of casing, with 40 additional sacks of cement later, to fill hole to cellar floor. After reaming hole below casing, minor amounts of mud again came up around casing.

Notes from drill records—Continued

<i>Depth (feet)</i>	<i>Remarks</i>
1,101.....	Set 1,132 ft of 11¼-in., 47-lb J55 casing at 1,101 feet, and cut off top of casing at rotary table. Casing cemented with 560 sacks of Oilwell and construction cement mixed with water, treated with 850 pounds of salt for cement used on upper part of casing, and with 250 lb of CaCl ₂ for that used on lower part.
5,305.....	Hole bridged at 3,038-3,055 ft with 26 sacks of Oilwell cement preceded by 6 sacks of Cal-Seal. After a flow of gas was tested, a 10⅝-in. bit (no. 47) cleaned out bridges above 2,608 ft, and hole was then plugged back to 2,980 feet with 25 sacks of construction cement and 19 sacks of Oilwell cement, followed by 6 sacks of Cal-Seal. Seven-inch, 38-lb, N-80 Spang seamless casing then cemented at 2,785 ft. with 150 sacks of Oilwell cement made with 120 cu ft of water. Cement plugged hole to 2,783 ft. While pulling tester out of hole after a test of perforations at 2,690 ft, a ball-peen hammer was inadvertently dropped down hole, causing tubing to stick. Attempts to free tubing caused it to twist off, leaving a fish with the top at 46 feet. A week was spent fishing, and some of tubing was recovered after being shot in two at 178 feet. Heavy mud, circulated to kill gas shows, lost returns, and it was found that the 7-inch casing had been shot in two. A diamond-point pilot bit used to loosen the junk twisted off. Parted casing above 188 feet recovered; and after milling on top of casing, hole was filled with 80-pound mud and abandoned. A 23-inch piece of 10¼-inch tubing was welded to the 11¼-inch casing, with a 2-inch side port and a ½-inch pressure gauge connection at top, which is 2 feet above ground level.

DRILL AND CORE BITS

Cores were taken with Reed tools, using the PCC wire line core barrel with 7⅝-inch bit for 162 feet of coring, and the Kor King conventional barrel (K-550) with 6¼-inch bit for the other 92 feet. Six bits were used with each type of core barrel; all were rock bits except for one conventional drag bit.

Several types and sizes of drilling bits were used, from a 26-inch Security hole opener to a 9⅝-inch Hughes bit OSQ-3A, but the greatest footage was drilled by 18 Hughes OD bits. Other types of Hughes bits, as well as Security and Smith bits, were used. A graphic presentation of the bits employed is given on plate 21. Where a drill bit was used to ream a cored interval to the normal hole size and then to continue drilling to deepen the hole, the total footage penetrated is shown as drilling on the graphic log.

DRILLING MUD

The rock penetrated in Meade test well 1 included a large amount of shale which formed a natural mud

during most of the drilling. Twelve sacks of Aquagel were mixed with water for spudding in, and 9 sacks were added at 1,866 feet to maintain proper mud characteristics. At 3,930 feet, 34 more sacks were added to reduce the mud weight after the bit stuck temporarily in a tight spot. After a test for gas at 5,305 feet, 37 sacks of Aquagel were added to condition the mud; and after plugging back to 2,980 feet, the addition of 10 sacks of sodium bicarbonate reduced viscosity of the cement-cut mud. During fishing operations, 20 sacks of Baroid were used in 90-pound mud to kill the gas flow. The following table gives the mud characteristics while the well was being drilled.

Drilling-mud characteristics, Meade test well 1

Depth (ft)	Weight (lb per cu ft)	Viscosity (Marsh funnel sec)	Water loss (cc per 30 min)	Temperature (° F)
147	80	41		50
276	79	43		54
290	79	45		56
315	77	37		63
365	77	35		64
440	73	33		82
488	75	36		64
600	76	34		64
712	76	35		61
827	76	34		64
900	72	34		64
988	74	37		66
1,037	76	35		64
1,100	77	45		64
1,165	76	37		64
1,205	75	38		64
1,300	76	38		70
1,382	75	36		68
1,436	74	35		68
1,500	74	36		70
1,590	73	34		78
1,667	72	34		72
1,740	77	32		76
1,800	79	32		70
1,865	80	35		72
1,940	82	36		78
2,000	83	38		78
2,065	85	37		79
2,095	87	40		77
2,135	87	40		80
2,160	87	38		80
2,215	87	41		81
2,260	87	38		81
2,310	86	38		84
2,360	83	41		82
2,375	84	40		84
2,420	84	35		82
2,435	84	38		81
2,480	82	35		78
2,520	82	35		79
2,565	80	35		79

Drilling-mud characteristics, Meade test well 1—Continued

Depth (ft)	Weight (lb per cu ft)	Viscosity (Marsh funnel sec)	Water loss (cc per 30 min)	Temperature (° F)
2,620	81	35		81
2,670	80	35		78
2,700	81	35		78
2,732	81	35		79
2,770	81	35		79
2,806	81	36		79
2,845	82	35		79
2,872	82	35		79
2,905	82	35		79
2,950	81	35		78
2,970	81	35		74
2,975	82	36		78
3,010	82	36		76
3,055	83	43		78
3,090	83	41		82
3,136	82	41		80
3,163	83	42		78
3,208	82	42		82
3,248	84	42		83
3,290	85	42		81
3,325	84	42		80
3,360	85	42		80
3,400	86	43		82
3,435	84	40		82
3,470	85	43		80
3,503	86	43		80
3,530	86	43		80
3,550	83	40		83
3,560	85	43		80
3,568	84	41		79
3,625	83	41		80
3,650	85	42		80
3,680	84	42		82
3,702	84	42		82
3,725	84	40		82
3,755	85	41		81
3,782	84	41		83
3,810	86	42		82
3,825	84	40		82
3,838	87	43		82
3,875	85	41		82
3,910	87	41		82
3,932	86	44		82
3,975	81	38		83
4,010	79	40	8.0	82
4,042	80	40	9.0	83
4,083	80	40	8.5	83
4,114	80	40		82
4,140	80	41	8.0	82
4,150	80	42		82
4,169	81	44		82
4,180	81	44		82
4,217	80	42		82
4,260	81	41		82
4,308	81	40		82
4,378	81	41		82
4,440	81	41	7.5	83
4,464	81	42	7.5	82
4,507	81	36		82

Drilling-mud characteristics, Meade test well 1—Continued

Depth (ft)	Weight (lb per cu ft)	Viscosity (Marsh funnel sec)	Water loss (cc per 30 min)	Temperature (° F)
4,575	81	36	8.5	82
4,625	81	36		82
4,675	81	36	8.5	82
4,720	82	36	8.5	82
4,770	82	37		82
4,778	82	36		78
4,832	82	36	8.5	82
4,875	82	36	8.0	82
4,915	82	36		82
4,960	83	37	8.0	82
5,010	82	36	8.0	82
5,050	84	36	8.0	82
5,115	85	37	8.0	82
5,173	83	36		82
5,207	85	37		82
5,260	83	36	8.5	81
5,300	79	33		82

HOLE DEVIATION

The deviation of the hole from vertical was very low throughout its depth. The maximum angle of 45' was reached at three points between 3,700 and 4,300 feet, which were separated by intervals having no deviation at all. Above 3,700 and below 4,300 feet, the deviation was commonly less than 30', except at 1,190 and 1,375 feet where it was 40'. Measurements were made with a Totco (Technical Oil Tool Corp.) Recorder.

ELECTRIC LOGGING

An electric log of the well was made from 93 to 5,204 feet with 6 runs of Schlumberger equipment, as shown below:

Run	Depth (feet)
1	97-1, 038
2	93-1, 101
3	1, 101-2, 288
4	2, 288-3, 552
5	3, 552-4, 184
6	4, 184-5, 204

The film of the first run was light struck, so the second run was made to replace it. The bottom 100 feet of the well was not logged because it was drilled after run 6 was made. A seventh run, from 258 to 2,748 feet, was made to locate the top of the cement after setting a 7-inch casing.

The spontaneous potential and the long- and short-normal curves are shown on the graphic log (pl. 21). The lateral curve, consisting of intermittent short records made between 1,200 and 4,170 feet, is not shown because it adds little to the information recorded by the other curves.

KAOLAK TEST WELL 1

Location: Lat 69°56' N., long 160°14'51'' W.
Elevation: Ground, 164 feet; kelly bushing, 178 feet.
Spudded: July 21, 1951.
Completed: November 12, 1951; dry and abandoned.
Total depth: 6,952 feet.

Kaolak test well 1 is the westernmost test in Naval Petroleum Reserve No. 4 (see fig. 23) and was drilled to determine the reservoir characteristics in this hitherto untested area, and to determine whether oil or gas were present. The test well is on the banks of a short tributary of the Kaolak River, a meandering north-flowing stream that crosses the flat, marshy, lake-dotted coastal plain of northern Alaska before entering a lagoon on the Arctic Ocean. (See fig. 26.) The well site is about 130 miles southwest of Barrow, on tundra-covered ground that is permanently frozen to a depth of several hundred feet. No field geology has been done in the vicinity, as outcrops are lacking; the drill site was on an anticline defined by a seismograph survey made by United Geophysical Co., Inc. in 1950; seismic reflections suggested the presence of alternating sandstone and shale between 2,000 and 8,000 feet.

The anticline is about 12 miles long and 4 miles wide, with approximately 300 feet of closure 5,000 feet below the surface. (See fig. 26.) Its long axis trends nearly east, and seismograph work shows it to be paralleled on the south by other, smaller folds, but the beds to the north rise steadily about 5,000 feet in 60 miles in a regional trend. At a depth of 10,000 feet no closure is present, but a south-plunging nose interrupts the regional southerly dip in the same area.

An airborne magnetometer survey by the U. S. Geological Survey in cooperation with the U. S. Navy in 1945 and 1946 shows a gradual decrease in magnetic intensity southward from Barrow and Kaolak which probably reflects the southerly dip mentioned above. A gravity survey conducted by the United Geophysical Co., Inc., in 1950 shows no significant change in gradient in the vicinity of the Kaolak test well.

Kaolak test well 1 was drilled through Cretaceous rocks to nearly 7,000 feet, where operations were suspended because the safe capacity of the rig with 4½-inch drill pipe had been reached. A change to 3½-inch pipe was planned, which would enable the well to be deepened to the desired depth of 7,500-8,000 feet, but while waiting for favorable conditions to freight the lighter pipe to the hole, a violent windstorm destroyed the derrick. The test was then abandoned because it had found only faint shows of oil and the sandstone beds penetrated were impermeable and apparently water bearing.

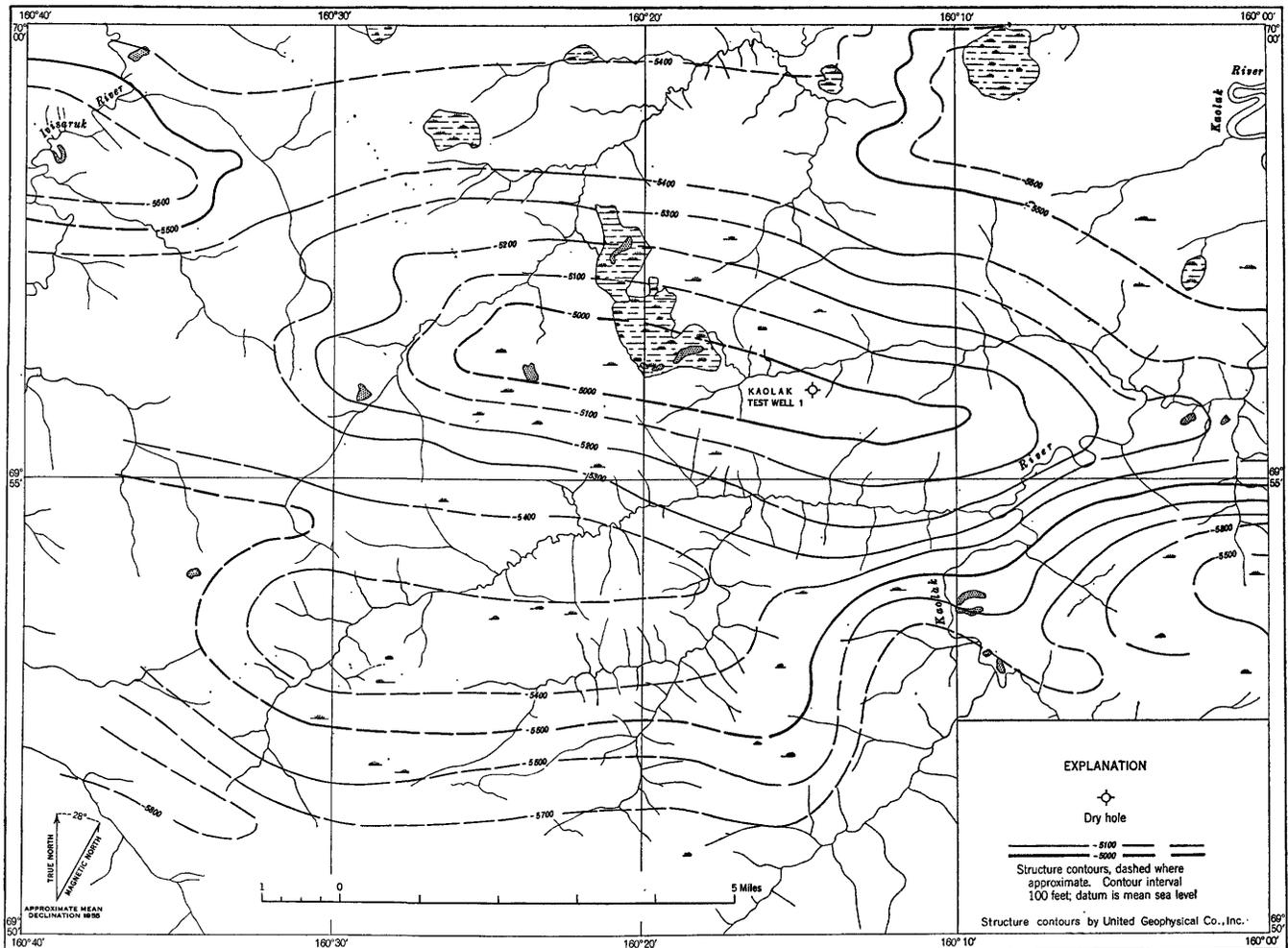


FIGURE 26.—Map showing location of Kaolak test well 1; structure contours drawn on a seismic horizon in Cretaceous rocks.

STRATIGRAPHY

From the ground level to 113 feet, the test was drilled through unconsolidated silt and clay overlying sandy gravel composed of well-rounded grains and granules of chert. The sediments lithologically resemble, and probably represent, the Pleistocene marine Gubik formation outcropping on the Arctic coastal plain, although microfossils typical of the formation elsewhere are lacking in this hole.

Between 113 and 1,175 feet, the rock is composed largely of very fine- to medium-grained sandstone that is commonly argillaceous and silty, with some clay shale, abundant clay ironstone, a few thin coal beds, and a minor amount of limestone (at 320-340 feet). Below 1,175 feet the strata include much coal, some beds of which are at least 17 feet thick. The coal beds above 2,300 feet are thicker and more closely spaced than they are below that depth; they are interbedded with medium-dark-gray clay shale, medium-gray siltstone, and medium-light-gray argillaceous sandstone. A minor amount of clay ironstone is also present. Two

beds, 50 and 35 feet thick, of light-gray fine- to medium-grained sandstone separated by clay shale are present between 3,140 and 3,270 feet; the sandstone beds are impermeable and had only a faint stain of oil. From 3,270 feet to the bottom, the drill penetrated medium-dark-gray clay shale. A few coal beds were noted as low as 4,600 feet, and several thin beds of medium-gray siltstone and very fine-grained sandstone to a depth of 6,500 feet.

The abundance of coal or clay ironstone and the scarcity of fossils in the beds above 4,600 feet suggest that they are predominantly nonmarine, although a very few Foraminifera (see p. 374) and possibly the sandstone beds at 3,140-3,270 feet indicate an occasional episode of marine deposition. In Meade test well 1, nearly 70 miles east of Kaolak test well 1, and in other test wells to the east, the nonmarine rocks of the Nanushuk group are included in the Chandler formation. In the closest outcrops, 20 miles to the southwest, the nonmarine rocks have been referred to the Corwin formation, which is equivalent to part of

the Chandler formation (Sable, 1956, p. 2642). Correlation between these widely separated points is uncertain, but in order to retain the terminology used in other test wells in the Reserve, the nonmarine sequence above 4,600 feet is here tentatively assigned to the Chandler formation.

Several specimens of *Verneuilinoides borealis* Tappan at 4,625 feet and an assemblage of Foraminifera at 6,367-6,387 feet suggest the presence of the *Verneuilinoides borealis* faunal zone. (See page 373.)

Bergquist (p. 374) points out that both the species and the manner of preservation of the fauna from the Kaolak well suggest correlation of the section with the Corwin and Kukpowruk formations rather than the formations present in the wells to the east. He also states that the fauna here is meager compared with its more typical occurrence in more easterly wells; however, lithologic evidence suggests that the rocks below 4,600 feet represent the Topagoruk formation, a marine shale which is in part equivalent to the predominantly sandy Kukpowruk formation which crops out to the southwest.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

[Where no cores are listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
----	0-14	Kelly bushing to ground level.
----	14-80	No ditch samples available; Robert Rutledge, an Arctic Contractors' geologist, notes: 0-30 ft, silt, loose unconsolidated mantle; 30-70 ft, clay shale, light-gray, soft, poor cleavage; 70-113 ft, sand and gravel.
----	80-113	Surface gravel and sand of well-rounded black, yellow, and red chert in coarse-sand size and pebbles as much as one-fourth inch in diameter.
----	113-120	Coal, black, shiny, with blocky fracture; some black carbonaceous shale. Top of Chandler formation at 113 ft.
----	120-140	Clay ironstone, light- to grayish-brown, very slightly calcareous, hard; and medium-light-gray slightly calcareous nonsilty clay shale.
----	140-150	Black carbonaceous shale, coal, gray clay shale, and minor noncalcareous slightly argillaceous light-olive-gray siltstone.
----	150-160	Sandstone, very fine-grained, silty, friable; angular to subangular clear quartz grains, commonly frosted or finely pitted; white quartz and chert rare; green and gray rock fragments common; mica, pyrite, and glauconite absent.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	160-190	Sandstone, medium-light-gray, very fine-to fine-grained, slightly to very argillaceous, slightly calcareous; composed of subangular to rounded grains of clear and white quartz with some white and gray chert and dark rock fragments. Some clay ironstone and small amount of silty clay shale in lower 10 ft.
----	190-200	Clay ironstone, yellowish-gray, with small amount of medium-light-gray clay shale.
----	200-210	Siltstone, medium-light-gray, very argillaceous, noncalcareous.
----	210-217	No sample.
1	217-237	Recovered 15 ft: Microfossils absent. 1 ft 1 in., clay shale, medium-dark-gray, noncalcareous, badly infiltrated with drilling mud. Light-olive-gray claystone 1 in. thick, at top. 1 in., siltstone, medium-light-gray, very argillaceous, noncalcareous, with carbonaceous material on partings. 11 in., coal, black, laminated to blocky, subvitreous, with black nonmicaceous clay shale laminae in upper part. 4 in., siltstone as above, infiltrated with drilling mud. 6 in., clay shale, dark-gray, with carbonaceous flakes, badly infiltrated with drilling mud. 8 in., coal, black, laminated. 1 ft 1 in., clay shale, medium-dark-gray to black, carbonaceous, with abundant coaly plant fragments. Infiltrated with drilling mud. 3 in., coal as above. 1 ft 2 in., clay shale, medium-dark-gray, noncalcareous, slightly bentonitic, infiltrated with drilling mud. Beds lie flat (?). 1 ft 1 in., sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, noncalcareous, very slightly micaceous; composed of subangular to angular white and clear commonly frosted quartz grains, and some white and gray chert and dark rock fragments. Carbonaceous streaks are scattered throughout. Grades into siltstone below. 10 in., siltstone, as above, very badly infiltrated with drilling mud. Grades into clay shale. 10 in., clay shale, medium-gray, very silty, noncalcareous. 11 in., claystone, light-olive-gray, very silty, noncalcareous, slightly bentonitic. 5 in., clay shale, medium-dark-gray, badly infiltrated with drilling mud.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		7 in., claystone, light-olive-gray, slightly silty, slightly bentonitic.
		1 ft 9 in., siltstone, medium-light-gray, slightly to very argillaceous, noncalcareous. Grades into siltstone.
		9 in., siltstone, medium-light-gray, very argillaceous, slightly calcareous, with abundant sandy patches and a few carbonaceous partings; crossbedded in part.
		9 in., claystone, light-olive-gray, slightly calcareous. Grades into unit below.
		10 in., clay shale, medium-dark-gray, with carbonaceous laminae. Grades into coal.
----	237-267	2 in., coal, with laminae of black shale.
----	267-277	Clay shale, medium-light-gray, clay ironstone, and small amount siltstone.
----	277-287	Sandstone, with some very silty shale and coal.
----	287-297	Clay shale, siltstone, and clay ironstone with small amount sandstone.
----	297-307	Sandstone with small amount siltstone, clay shale, and clay ironstone; 2 small pieces brownish- to reddish-yellow translucent to transparent resinous amber.
----	307-327	Coal, sandstone, and siltstone.
----	327-347	Clay ironstone with some coal, black and gray clay shale, and small amount of medium-gray very silty limestone.
----	347-357	Clay ironstone with gray clay shale and medium-gray dense argillaceous slightly silty limestone.
----	357-367	Sandstone with some clay ironstone.
----	367-397	Clay ironstone, gray shale, and siltstone.
----		Sandstone, medium-light-gray, very fine-grained, very silty, noncalcareous; composed of angular to subangular clear quartz, with some clay ironstone and minor gray clay shale.
----	397-407	Sandstone as above, and medium-grained noncalcareous slightly carbonaceous and argillaceous salt-and-pepper sandstone of subangular to subrounded quartz grains with many gray chert and dark rock fragments.
----	407-417	Sandstone, very fine-grained, with a small amount of salt-and-pepper sandstone.
----	417-420	No sample.
2	420-440	Recovered 20 ft: Microfossils very rare. 3 ft sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, noncalcareous, very slightly bentonitic, with scattered flakes of carbonaceous material throughout. Effective porosity at 422 and 429 ft 12.7 percent and 11.0 percent, respectively; samples from both depths impermeable.
		17 ft, sandstone, medium-light-gray,

Lithologic description—Continued

Core	Depth (feet)	Remarks
		fine-grained, very silty and argillaceous, poorly indurated, noncalcareous. Abundant flakes of carbonaceous material present throughout and concentrated on partings; minor amounts of bentonite and limonite also scattered throughout. Medium-gray noncalcareous clay shale occurs as beds 1 in. thick at 436 ft, 3 in. thick at 440 ft, and as thin lenses elsewhere. Some areas infiltrated with drilling mud. Dips range from 0° to 5°.
----	440-540	Sandstone, with small amount of clay ironstone at 450-460 ft and 520-530 ft and small amount of gray clay shale at 520-540 ft. Sandstone is very fine-grained in upper 20 ft, fine to medium grained below.
----	540-550	Coal, black, shiny; blocky fracture.
----	550-560	Clay ironstone with small amount of sandstone.
3	560-580	Recovered 20 ft: Microfossils absent. 1 ft, clay shale, dark-gray, fissile, noncalcareous, nonmicaceous. Grades into clay shale.
		19 ft, clay shale, medium-gray, bentonitic, noncalcareous, nonmicaceous, with subconchoidal fracture to shaly cleavage. Yellowish-gray hard noncalcareous 2-in.-thick clay ironstone at 565 ft. and 579 ft. A 9-in. segment between 568 ft and 569 ft consists of fissile dark clay shale like that at top of core.
----	580-590	Sandstone, very fine-grained, and medium-gray clay shale.
----	590-670	Sandstone, medium-gray, very fine-grained, very silty and argillaceous, carbonaceous, noncalcareous; contains white quartz and gray and dark rock fragments. Becomes coarser, salt-and-pepper sandstone from 630 to 640 ft. Clay shale in upper 10 ft.
----	670-680	Clay ironstone with fine-grained sandstone as above.
----	680-690	Coal.
----	690-700	Sandstone, fine-grained, as above; with minor amount of clay ironstone and gray clay shale.
----	700-760	Sandstone, fine-grained, clay ironstone, and gray clay shale.
----	760-762	No sample.
4	762-782	Recovered 18 ft 6 in.: Microfossils absent. 5 ft 9 in., clay shale, medium-gray, noncalcareous, nonmicaceous, with a poor shaly cleavage which indicates irregular dip of as much as 5°. 3 ft 3 in., clay shale, grayish-black, carbonaceous, noncalcareous; poor to fair shaly cleavage. Upper 6 in. is

Lithologic description—Continued

Core	Depth (feet)	Remarks
		badly infiltrated with drilling mud. Grades into siltstone.
		1 ft 3 in., siltstone, medium- to medium-light-gray, very argillaceous, calcareous, very slightly micaceous, with carbonaceous patches and partings, and carbonized plant fragments. Thin sandy streaks present on some of bedding planes; silty shale streaks also present.
		1 ft 9 in., sandstone, medium-gray, very fine-grained, very silty and argillaceous, noncalcareous, nonmicaceous. Grades into unit below.
		1 ft 6 in., siltstone as above. Grades to unit below.
		4 ft, clay shale as at top of core; becomes silty with depth.
		6 in., drilling mud with coal fragments.
		6 in., coal, black, shiny, with blocky fracture.
----	782-800	Sandstone, fine-grained, with minor clay ironstone.
----	800-820	Clay shale, medium-light-gray, very silty, with a small amount of slightly calcareous siltstone.
----	820-830	Sandstone, clay ironstone, and clay shale.
----	830-930	Sandstone, fine-grained as above, with some coal in upper 30 ft, and fine- to medium-grained salt-and-pepper sandstone from 890-920 ft.
----	930-935	No sample.
5	935-941	Recovered 4 ft 5 in.: Microfossils absent. Sandstone, light- to medium-light-gray, fine- to medium-grained, very to slightly argillaceous and silty, salt-and-pepper. Lighter color characteristic of the finer grained, siltier units. Sandstone is noncalcareous and nonmicaceous and has flakes and fragments of carbonaceous material on partings. Sand consists of angular to subangular white and clear quartz grains with scattered dark grains. Coarser sand has larger proportion of gray and black chert grains. Pyrite and glauconite absent. Effective porosity at 937 ft 11.55 percent, but rock is impermeable.
----	941-980	Clay shale, gray, and fine-grained sandstone; sandstone increases with depth; coal in upper part.
6	980-1,000	Recovered 20 ft: Microfossils absent. 3 ft 2 in., siltstone, medium-gray, argillaceous, noncalcareous, slightly micaceous, with carbonaceous partings and scattered carbonized flakes. A few irregular bedding planes dip as much as 3°. Grades into claystone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		8 in., claystone, medium- to medium-light-gray, slightly silty, noncalcareous, with light-yellowish-gray slightly calcareous clay ironstone.
		4 ft, claystone, medium-dark-gray, noncalcareous, nonmicaceous, with scattered fragments of carbonized plant remains. Becomes darker, has shaly cleavage, and contains light-yellow clay ironstone at base of section. Grades into unit below.
		1 ft, clay shale, grayish-black, carbonaceous.
		1 ft 2 in., coal.
		6 ft 6 in., claystone, medium-gray, partly silty, noncalcareous; some parts have shaly cleavage.
		1 ft 1 in., interlaminated black carbonaceous shale and coal; coal increases with depth.
		1 ft 11 in., claystone as above; grades into unit below.
		6 in., clay shale, dark-gray, with coal laminae.
----	1,000-1,030	Clay shale, medium-light-gray, slightly calcareous, and medium-light-gray rare siltstone.
----	1,030-1,060	Clay shale as above, with minor clay ironstone.
----	1,060-1,070	Clay shale, siltstone, and clay ironstone.
----	1,070-1,080	Clay ironstone with small amount of clay shale.
----	1,080-1,090	Clay shale, light-olive-gray; calcareous siltstone; and very fine-grained calcareous sandstone.
----	1,090-1,130	Siltstone, medium-gray, very calcareous; and medium-gray silty and argillaceous very tight very calcareous sandstone.
----	1,130-1,140	Siltstone and clay shale.
----	1,140-1,150	Sandstone and siltstone, medium-gray, very calcareous; and clay shale.
----	1,150-1,160	Sandstone with small amount of clay shale.
----	1,160-1,170	Sandstone and clay shale.
----	1,170-1,183	No sample.
7	1,183-1,203	Recovered 17 ft: Not sampled for microfossils.
		7 in., claystone fragments, medium-gray, infiltrated with drilling mud.
		16 ft 5 in., coal, black, shiny, with blocky to shaly cleavage; with a few thin beds of dark-gray carbonaceous claystone.
----	1,203-1,210	Coal.
----	1,210-1,230	Clay ironstone, clay shale, and medium-light-gray noncalcareous very fine-grained sandstone.
----	1,230-1,240	Coal and sandstone with small amount of clay ironstone and clay shale.
----	1,240-1,250	Clay shale with small amount of coal, sandstone, and clay ironstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	1, 250-1, 270	Coal, with small amount of clay shale and siltstone in upper 10 ft.
----	1, 270-1, 280	Sandstone, medium-light-gray, fine-grained.
----	1, 280-1, 290	Clay shale, medium-light-gray, slightly calcareous in part, with small amount of coal and siltstone.
----	1, 290-1, 300	Coal, with minor clay shale and siltstone.
----	1, 300-1, 310	Sandstone, very fine-grained, very silty, noncalcareous.
----	1, 310-1, 320	Coal and sandstone, with some clay shale and siltstone.
----	1, 320-1, 330	Claystone, medium-dark-gray, calcareous.
----	1, 330-1, 340	Clay shale, coal, and sandstone.
----	1, 340-1, 350	Sandstone with minor siltstone.
----	1, 350-1, 360	Clay shale with some clay ironstone.
----	1, 360-1, 380	Coal, with sandstone and clay shale in upper part.
----	1, 380-1, 383	No sample.
8	1, 383-1, 400	Recovered 16 ft: Microfossils absent. 3 ft 8 in., clay shale, medium-dark-gray, with carbonized plant remains scattered throughout, and 2- to 3-in.-thick inter laminations of coal and black shale that total about 20 percent of unit. 12 ft 4 in., siltstone, very argillaceous, medium- to medium-light-gray, calcareous, with three 6-in. beds of inter laminated dark-gray carbonaceous shale and coal at 1,387 ft, 1,495 ft, and 1,496 ft; 2-ft bed of shaly coal at 1,493-1,495 ft.
----	1, 400-1, 410	Claystone, medium-dark-gray, calcareous.
----	1, 410-1, 430	Siltstone, with sandstone and some clay shale in upper half.
----	1, 430-1, 440	Clay ironstone, clay shale, and siltstone.
----	1, 440-1, 470	Coal, black, shiny, with minor clay shale, siltstone, and clay ironstone.
----	1, 470-1, 480	Siltstone, light-olive-gray, noncalcareous.
----	1, 480-1, 490	Coal with some sand and minor clay ironstone and clay shale.
----	1, 490-1, 500	Siltstone; grades to clay shale.
----	1, 500-1, 510	Sandstone, fine- to medium-grained.
----	1, 510-1, 516	No sample.
9	1, 516-1, 536	Recovered 20 ft: Microfossils absent. 16 ft, claystone, medium-light-gray, very silty, micaceous (muscovite?), calcareous, with irregular medium-gray clay and light-gray silt and sand streaks, dip 20° or less and slightly distorted, probably by contemporaneous deformation. Minute normal and reverse faults with less than 1 in. throw also present, probably of same origin. Clay-ironstone nodules present though rare. 9 in., clay shale, grayish-black, with abundant coal laminae. Grades into unit below. 2 ft 5 in., coal, black, with shaly cleavage grading to blocky fracture. Frag-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		ments of grayish-black shale from a 3-in. bed at 1,524 ft have slickensides on most surfaces.
		10 in., clay shale, medium-dark-gray, with abundant carbonized plant fragments scattered throughout; slickensides on many surfaces.
----	1, 536-1, 550	Clay ironstone with clay shale.
----	1, 550-1, 560	Siltstone, medium-light-gray, slightly calcareous, with some clay shale.
----	1, 560-1, 580	Coal with small amount of black carbonaceous shale.
----	1, 580-1, 590	Siltstone and sandstone, with some gray clay shale.
----	1, 590-1, 630	Coal, with minor black shale in upper 10 ft and small amount of gray clay shale in lower 30 ft.
----	1, 630-1, 640	Gray clay shale and siltstone with minor coal, sandstone and clay ironstone.
----	1, 640-1, 650	Sandstone, salt-and-pepper, fine-grained, noncalcareous, with some coal and small amount of clay shale.
----	1, 650-1, 657	Sandstone, salt-and-pepper.
10	1, 657-1, 677	Recovered 5 ft: Microfossils absent. Sandstone, medium-light-gray, fine- to medium-grained, salt-and-pepper, very silty and argillaceous, noncalcareous, massive, uniform. Grains subangular, and composed of white and clear quartz with some gray and white chert and dark rock fragments. Mica, glauconite, and pyrite absent. Impermeable sample from 1,665 ft had effective porosity of 14.37 percent.
11	1, 677-1, 693	Recovered 13 ft: Microfossils absent. 3 ft, sandstone as above; slightly finer grained at top; carbonaceous flakes on very rare partings at base of section. Impermeable sample from 1,678 ft has effective porosity of 11.96 percent. 10 ft, clay shale, medium-gray, noncalcareous, nonmicaceous, with scattered carbonaceous flakes. Coal 8-10 in. thick, with shaly laminae; at 1,680, 1,683 and 1,692 ft, is badly infiltrated with drilling mud.
----	1, 693-1, 700	Sandstone, very fine-grained, with some coal and clay shale.
----	1, 700-1, 710	Coal.
----	1, 710-1, 720	Sandstone, very fine-grained, with some coal and gray clay shale.
----	1, 720-1, 730	Coal and gray clay shale.
----	1, 730-1, 740	Sandstone, very fine-grained, with small amount of coal.
----	1, 740-1, 750	Coal, gray clay shale, and siltstone.
----	1, 750-1, 800	Coal, with some gray shale and sandstone; small amount black shale in upper 10 ft.
----	1, 800-1, 810	Sandstone, light-medium-gray, very fine-grained, noncalcareous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	1, 810-1, 814	No sample.
12	1, 814-1, 832	Recovered 15 ft: Microfossils absent. 2 ft 1 in., claystone, medium-gray, silty, noncalcareous, with scattered carbonized plant fragments. 12 ft 11 in., siltstone, light-medium-gray, argillaceous, with sandy streaks; coarsens and becomes calcareous with depth. Irregular and commonly crossbedded carbonaceous partings and clay laminae present throughout; 6-in. beds of claystone with coal laminae present at 1,827 and 1,829 ft.
-----	1, 832-1, 840	Coal with small amount of gray shale.
-----	1, 840-1, 850	Coal with clay ironstone and gray clay shale.
-----	1, 850-1, 900	Clay shale, gray; grades to light-medium-gray calcareous siltstone; rare sandstone at 1,860-1,870 ft.
-----	1, 900-1, 910	Coal with clay shale and minor clay ironstone.
-----	1, 910-1, 920	Siltstone and clay shale.
-----	1, 920-1, 930	Clay shale.
-----	1, 930-1, 940	Sandstone, very fine-grained, very silty, calcareous.
-----	1, 940-1, 970	Coal, with some clay shale at 1,950-1,960 ft.
-----	1, 970-1, 990	Sandstone, light-gray, very fine-grained, calcareous to very slightly calcareous.
-----	1, 990-2, 010	Coal, gray clay shale, and sandstone.
-----	2, 010-2, 020	Coal.
-----	2, 020-2, 026	No sample.
13	2, 026-2, 046	Recovered 6 ft 6 in.: Microfossils absent. 5 in., drilling mud with chips of shale. 2 ft 4 in., clay shale, medium-dark-gray, noncalcareous, nonmicaceous, with poor shaly cleavage; scattered carbonaceous flakes and a few patches of light-yellowish-gray slightly calcareous clay ironstone present. Laminated black shaly coal 1 in. thick, at base. 3 ft 9 in., claystone, medium-gray, silty, slightly calcareous in part; laminae of calcareous sandy silt, commonly crossbedded, total 15 percent of unit.
-----	2, 046-2, 060	Sandstone with some gray clay shale.
-----	2, 060-2, 070	Clay shale, medium-gray, slightly calcareous in part.
-----	2, 070-2, 080	Clay shale, gray, with coal, clay ironstone, and black clay shale.
-----	2, 080-2, 090	Clay shale, gray, with small amount of sandstone and coal.
-----	2, 090-2, 100	Sandstone with some coal and gray clay shale.
-----	2, 100-2, 110	Coal with minor clay ironstone and clay shale.
-----	2, 110-2, 120	Clay shale, gray, with coal and minor black clay shale, clay ironstone, and sandstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	2, 120-2, 130	Siltstone with some gray clay shale and sandstone.
-----	2, 130-2, 150	Siltstone, gray clay shale, and sandstone with some black shale and coal, and clay ironstone in upper part.
-----	2, 150-2, 160	Sandstone, light-gray, very silty and argillaceous, calcareous, salt-and-pepper.
-----	2, 160-2, 180	Coal, with minor gray clay shale in upper 10 ft.
-----	2, 180-2, 200	Clay shale, gray, and coal with minor black shale and clay ironstone.
-----	2, 200-2, 206	No sample.
14	2, 206-2, 225	Recovered 18 ft: Microfossils absent. 13 ft 11 in., claystone, medium-dark-gray, noncalcareous, slightly silty in part, with scattered flakes and fragments of carbonized plants. Grades into unit below. 1 ft 11 in., interbedded light-yellowish-gray slightly calcareous clay ironstone and claystone as above in irregular beds as much as one-half inch thick; approximately 30 percent ironstone. 2 ft 2 in., clay shale, medium-dark to dark-gray, with abundant partings, laminae, and thin coal beds. Some slickensided surfaces in basal 1 ft.
-----	2, 225-2, 230	Clay shale and very argillaceous medium-gray calcareous siltstone.
-----	2, 230-2, 240	Clay shale with some coal.
-----	2, 240-2, 250	Clay shale with some clay ironstone.
-----	2, 250-2, 260	Coal.
-----	2, 260-2, 270	Clay shale with siltstone.
-----	2, 270-2, 280	Clay shale, and coal, with siltstone.
-----	2, 280-2, 290	Clay shale with some coal and a little black shale.
-----	2, 290-2, 300	Clay shale, siltstone, coal, and a little black shale.
-----	2, 300-2, 310	Coal with a minor amount of clay shale.
-----	2, 310-2, 330	Clay shale with small amount of coal in upper half, siltstone in lower half.
-----	2, 330-2, 350	Clay shale with some coal, and black carbonaceous clay shale.
-----	2, 350-2, 370	Clay shale with small amount of coal.
-----	2, 370-2, 390	Clay shale with coal and black shale.
-----	2, 390-2, 400	Clay shale.
15	2, 400-2, 415	Recovered 15 ft: Microfossils absent. 5 ft, interbedded claystone, medium-dark-gray, slightly silty in part, noncalcareous; medium-gray very argillaceous noncalcareous siltstone, slightly sandy in a few places. Single beds are 3-8 in. thick, and grade into overlying and underlying beds. 2 ft 4 in., interlaminated medium-dark-gray clay shale and medium-light-gray argillaceous sandy siltstone, crossbedded in part. Laminae have sharp contacts and are irregular and wavy.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		A 4-in. section with coaly laminae is 1 ft above base of section; clay ironstone nodule 1½ in. thick occurs 4 in. above the underlying sandstone.
		1 in., sandstone, light gray, fine- to medium-grained, very argillaceous and silty, noncalcareous, nonmicaceous, salt-and-pepper; composed of sub-angular to subrounded grains of white and clear quartz, gray chert, and dark rock fragments. Carbonaceous grains and partings common.
		4 in., clay shale and siltstone as above.
		2 ft 3 in., sandstone as above.
		5 ft, interlaminated clay shale and siltstone as above.
----	2, 415-2, 420	Sandstone, salt-and-pepper, with some gray shale and minor siltstone.
----	2, 420-2, 430	Clay ironstone with minor clay shale.
----	2, 430-2, 453	No sample.
16	2, 453-2, 473	Recovered 13 ft: Microfossils absent. 3 ft, sandstone as in core 15; irregular coaly fragments and laminae of argillaceous silt also present. Abundant rounded medium-gray clay shale fragments (as much as 1 in. in diameter) with long axes horizontal, are present in top 3 in. of section. A sample at 2,453 ft has no permeability; effective porosity is 11.9 percent.
		11 in., interbedded medium-dark-gray clay shale, coal, and light-yellowish-gray clay ironstone; beds are less than one-half inch thick.
		2 ft 1 in., interbedded shaly coal and black, noncalcareous, nonmicaceous clay shale; slickensides on some shale fragments.
		2 ft, clay shale, medium-dark-gray, noncalcareous, nonmicaceous, with poor shaly cleavage; fragments of carbonized plants present; thin beds of yellowish-gray clay ironstone grade into beds of shale.
		5 ft, coal, black, shiny, blocky to shaly cleavage.
----	2, 473-2, 500	Clay shale, with small amount of siltstone and a very little sandstone.
----	2, 500-2, 520	Clay shale.
----	2, 520-2, 530	Clay shale with small amount of black shale, coal, and sandstone.
----	2, 530-2, 540	Sandstone, medium-light-gray, very fine-grained, very silty, calcareous; with clay shale and some coal.
----	2, 540-2, 560	Clay shale with minor sandstone and coal.
----	2, 560-2, 570	Sandstone with clay shale.
----	2, 570-2, 580	Clay shale with some coal and clay ironstone.
----	2, 580-2, 590	Coal and gray clay shale.
----	2, 590-2, 600	Coal with a little clay shale.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	2, 600-2, 607	No sample.
17	2, 607-2, 618	Recovered 10 ft: Microfossils absent. 2 ft 4 in., fragments of medium-dark-gray claystone, with coal fragments in upper part, badly infiltrated with drilling mud.
		7 ft 8 in., interbedded claystone and coal as above; coal beds, more common in the upper half, are 3-6 in. thick and total about 30 percent of the rock. Claystone contains scattered fragments of carbonized plants. Shaly cleavage in a 2-in. bed at top dips 22°.
----	2, 618-2, 620	Clay shale and siltstone with a little sandstone.
----	2, 620-2, 630	Siltstone with small amount of clay shale and coal.
----	2, 630-2, 650	Clay shale, with small amount of black shale and very little siltstone in the upper half.
----	2, 650-2, 660	Coal and clay shale.
----	2, 660-2, 670	Clay shale with coal.
----	2, 670-2, 680	Clay shale with coal and black shale.
----	2, 680-2, 690	Coal.
----	2, 690-2, 700	Clay shale with some siltstone and black shale.
----	2, 700-2, 710	Clay shale with a little siltstone and coal.
----	2, 710-2, 720	Coal.
----	2, 720-2, 740	Clay shale with sandstone and some coal.
----	2, 740-2, 750	Sandstone with some clay shale and coal.
----	2, 750-2, 770	Sandstone, fine-grained, noncalcareous, salt-and-pepper, with a little shale and coal.
----	2, 770-2, 780	Clay shale with minor coal and sandstone.
----	2, 780-2, 791	Coal with a little gray clay shale.
18	2, 791-2, 811	Recovered 20 ft: Microfossils common. 6 ft 5 in., claystone, medium-dark-gray, very slightly silty, slightly calcareous in part. 3 ft 4 in., claystone as above but with abundant laminae of silty calcareous medium-gray clay shale that dip 10°. 3 in., claystone, medium-dark-gray, noncalcareous, nonmicaceous, with conchoidal fracture. 6 ft 8 in., claystone, medium-dark-gray, as at top of core, with 2- to 3-in. beds of black coal, with shaly cleavage, at 2,802 and 2,807 ft. Some laminae of medium-light-gray silty clay shale and rare streaks of light-yellowish-gray clay ironstone. 1 ft 8 in., coal, black, shiny, blocky fracture to shaly cleavage. 1 ft 8 in., claystone, medium-dark-gray, slightly silty in part, noncalcareous, with a few clay ironstone streaks.
----	2, 811-2, 850	Clay shale, gray, very slightly calcareous, with some siltstone at 2,820-2,830 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	2, 850-2, 860	Clay shale with small amount of coal and siltstone.
----	2, 860-2, 870	Clay shale with siltstone.
----	2, 870-2, 880	Clay shale and coal with minor siltstone.
----	2, 880-2, 890	Clay shale with minor sandstone and coal.
----	2, 890-2, 900	Clay shale, siltstone, black shale, and coal.
----	2, 900-2, 910	Clay shale and siltstone.
----	2, 910-2, 920	Coal with minor clay shale.
----	2, 920-2, 940	Clay shale with small amount coal, and minor sandstone in upper half.
----	2, 940-2, 945	No sample.
19	2, 945-2, 957	Recovered 11 ft 6 in.: Microfossils absent. 2 ft 8 in., claystone, medium-dark-gray, noncalcareous, nonmicaceous; with conchoidal fracture, and rare carbonaceous flakes and fragments of carbonized plants. 1 ft 1 in., siltstone, medium-light-gray, slightly calcareous, with irregular clay shale and carbonaceous partings dipping 3° or less. 7 ft 9 in., claystone as above, with 1-in. beds of slightly calcareous clay ironstone 1 ft and 4 ft below top. Three 6-in. intervals containing crossbedded siltstone laminae (dip as much as 25°) in lower 5 ft of core.
----	2, 957-2, 960	Clay shale with small amount siltstone.
----	2, 960-2, 970	Sandstone and clay shale.
----	2, 970-2, 990	Clay shale with small amount siltstone and a little coal.
----	2, 990-3, 000	Sandstone and clay shale.
----	3, 000-3, 020	Clay shale and coal with minor clay ironstone in lower part.
----	3, 020-3, 030	Coal with some clay shale.
----	3, 030-3, 050	Clay shale with coal.
----	3, 050-3, 060	Clay shale with some coal and a little siltstone and sandstone.
----	3, 060-3, 070	Clay shale and coal.
----	3, 070-3, 080	Clay shale and siltstone with coal.
----	3, 080-3, 090	Clay shale.
----	3, 090-3, 100	Clay shale with minor clay ironstone.
----	3, 100-3, 110	Coal with a little clay shale.
----	3, 110-3, 120	Clay shale with some siltstone and minor clay ironstone.
----	3, 120-3, 140	Clay shale with some siltstone and small amount of coal.
----	3, 140-3, 150	Sandstone, light-gray, fine- to very fine-grained, noncalcareous, salt-and-pepper, with a little gray clay shale.
----	3, 150-3, 156	No sample.
20	3, 156-3, 176	Recovered 20 ft: Microfossils absent. Sandstone, light-gray, fine- to medium-grained, very silty and argillaceous, noncalcareous, salt-and-pepper; a few 2- to 3-in. sections have interlaminated carbonaceous material and sand; dip of 8°. Scattered patches and partings of carbonaceous material also present.

Lithologic description—Continued

Core	Depth (feet)	Remarks								
----	----	At 3,158 and 3,176 ft the sandstone has effective porosity of 8.33 and 9.30 percent, respectively, but is impermeable at both depths.								
21	3, 176-3, 192	Recovered 16 ft: Microfossils absent. 7 ft 4 in., sandstone as above; oil stain noted by well geologist in basal 6 in. gave no cut or residue in CCl ₄ (after core was in a heated drying rack 2 or 3 hrs). 1 ft 7 in., claystone, medium-gray, slightly calcareous in part; a few calcite veinlets crisscrossed in basal 6 in. 7 ft 1 in., sandstone as above. Rounded white and gray chert and clay ironstone pebbles ½-1¼ in. in diameter form a conglomerate 2 in. thick, 2½ ft above base of sandstone. Six inches of oil-stained rock noted by well geologist at 3,191 ft gave a blackish-brown cut and residue in CCl ₄ ; sample from 3,187 ft gave no cut or residue. Two 6-in. segments of medium-gray claystone as above present in the lower 2 ft of core. Samples in following table impermeable to air.								
		<table border="1"> <thead> <tr> <th>Depth (feet)</th> <th>Effective porosity (percent)</th> </tr> </thead> <tbody> <tr> <td>3,184.....</td> <td>9.15</td> </tr> <tr> <td>3,187.....</td> <td>10.04</td> </tr> <tr> <td>3,191.....</td> <td>9.5</td> </tr> </tbody> </table>	Depth (feet)	Effective porosity (percent)	3,184.....	9.15	3,187.....	10.04	3,191.....	9.5
Depth (feet)	Effective porosity (percent)									
3,184.....	9.15									
3,187.....	10.04									
3,191.....	9.5									
----	3, 192-3, 210	Clay shale with some fine-grained salt-and-pepper sandstone; one piece of clay shale has aragonite veinlets.								
----	3, 210-3, 220	Coal and clay shale, with some siltstone and sandstone.								
----	3, 220-3, 230	Clay shale and siltstone.								
----	3, 230-3, 240	Sandstone, medium-light-gray, very fine-grained, calcareous, with some siltstone and clay shale.								
----	3, 240-3, 250	Sandstone, fine-grained, light-gray, very slightly calcareous, salt-and-pepper, with minor clay shale.								
----	3, 250-3, 256	Sandstone, salt-and-pepper.								
22	3, 256-3, 271	Recovered 15 ft: Microfossils absent. 14 ft 4 in., sandstone as in core 21, but with much less carbonaceous material. 8 in., claystone, dark-gray, noncalcareous, nonmicaceous, with common carbonized plant fragments.								
----	3, 271-3, 280	Clay shale with minor siltstone.								
----	3, 280-3, 290	Clay shale and siltstone.								
----	3, 290-3, 300	Clay shale.								
----	3, 300-3, 310	Clay shale with siltstone.								
----	3, 310-3, 320	Coal with some clay shale and siltstone.								
----	3, 320-3, 330	Clay shale with some siltstone.								
----	3, 330-3, 340	Clay shale and sandstone, light-gray, very fine-grained, noncalcareous.								

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	3, 340-3, 350	Sandstone, salt-and-pepper, with some clay shale and clay ironstone.
----	3, 350-3, 360	Siltstone, clay shale, coal and sandstone.
----	3, 360-3, 370	Clay shale with a little salt-and-pepper sandstone.
----	3, 370-3, 400	Clay shale with some siltstone.
----	3, 400-3, 410	Clay shale with coal.
----	3, 410-3, 440	Clay shale.
----	3, 440-3, 450	Clay shale and siltstone with sandstone and very small amounts of coal and clay ironstone.
----	3, 450-3, 460	Clay shale, with coal and a little siltstone.
----	3, 460-3, 470	Clay shale with some coal.
----	3, 470-3, 476	No sample.
23	3, 476-3, 496	Recovered 13 ft 6 in.: Microfossils absent. Claystone, medium- to medium-dark-gray, very silty to slightly silty, noncalcareous, slightly micaceous, with scattered irregular patches of carbonaceous material throughout.
----	3, 496-3, 500	Sandstone, very fine-grained, very silty and argillaceous, very slightly calcareous.
----	3, 500-3, 530	Clay shale, with small amount of siltstone, 3,510 to 3,520 ft.
----	3, 530-3, 540	Clay shale with some coal and small amount black shale.
----	3, 540-3, 560	Clay shale with some siltstone.
----	3, 560-3, 600	Clay shale with small amount siltstone at 3,570 to 3,590 ft.
----	3, 600-3, 610	Clay shale, gray, with some black shale and a little coal.
----	3, 610-3, 640	Clay shale, gray, with coal decreasing from 30 to 5 percent with depth.
----	3, 640-3, 660	Clay shale, gray, with minor black clay shale.
----	3, 660-3, 667	No sample.
24	3, 667-3, 679	Recovered 7 ft 6 in.: Microfossils absent. 3 ft 10 in., claystone, medium- to medium-dark-gray, noncalcareous, silty and micaceous toward base, with carbonized plant fragments scattered throughout. Two beds, 2- to 3-in. thick, of very fine-grained sandstone, as described below, are present in lower 1½ ft of unit. 2 ft., sandstone, very fine- to fine-grained, very silty and argillaceous, noncalcareous; composed of angular to subangular white and clear quartz with minor chert and flakes of carbonaceous material. Irregular crossbedded carbonaceous and argillaceous partings dip 5°-15°. 1 ft 8 in., interbedded black carbonaceous shale and coal, badly infiltrated with drilling mud.
----	3, 679-3, 690	Clay shale with some siltstone.
----	3, 690-3, 700	Clay shale with a little coal and minor siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	3, 700-3, 710	Clay shale with some siltstone.
----	3, 710-3, 730	Clay shale with minor clay ironstone in lower part.
----	3, 730-3, 740	Clay shale with small amount of coal and minor siltstone.
----	3, 740-3, 750	Clay shale.
----	3, 750-3, 760	Clay shale with small amount of sandstone.
----	3, 760-3, 770	Clay shale with small amount of siltstone.
----	3, 770-3, 780	Coal and clay shale.
----	3, 780-3, 800	Clay shale with small amount of siltstone in upper part.
----	3, 800-3, 820	Clay shale with some coal in upper part.
----	3, 820-3, 830	Coal.
----	3, 830-3, 840	Clay shale.
----	3, 840-3, 850	Clay shale with some siltstone.
----	3, 850-3, 870	Clay shale.
----	3, 870-3, 873	No sample.
25	3, 873-3, 881	No recovery.
26	3, 881-3, 892	Recovered 8 ft: Microfossils absent. Clay shale, medium-gray, noncalcareous, with poor shaly cleavage. Medium-light-gray noncalcareous siltstone laminae common, especially in lower third of core, where contemporaneous deformation has caused distortion of laminae. Rare dark-gray somewhat carbonaceous laminae.
----	3, 892-3, 900	Clay shale.
----	3, 900-3, 910	Clay shale, gray, with some black shale.
----	3, 910-3, 920	Clay shale with minor coal and siltstone.
----	3, 920-3, 970	Clay shale with minor coal and siltstone in lower part.
----	3, 970-3, 980	Clay shale with some sandstone.
----	3, 980-3, 985	No sample.
27	3, 985-4, 002	Recovered 17 ft: Microfossils absent. 10 ft, sandstone, light-gray, very fine- to fine-grained, very argillaceous and silty, noncalcareous; composed of angular to subangular white and clear quartz and rare dark fragments. At 3,988 ft an impermeable sample has effective porosity of 9.86 percent. Carbonaceous partings are common, and dip as much as 5°. Minute carbonaceous flakes scattered throughout. Sandstone slightly finer grained; argillaceous laminae common in lower 1½ ft; grades into unit below. 7 ft, clay shale, dark-gray, silty, very micaceous, with fair shaly cleavage. Laminae and thin sandy beds of silt at 3,998-3,999 ft and 4,001-4,002 ft. Flakes and fragments of carbonized plants common; two pelecypods (<i>Entolium</i> sp., identified by Ralph W. Imlay) found at 3,996 ft.
28	4, 002-4, 021	Recovered 14 ft: Microfossils absent. 2 ft, interlaminated dark-gray clay shale, medium-light-gray siltstone, light-gray

Lithologic description—Continued

Core	Depth (feet)	Remarks
		sandstone, all noncalcareous; carbonaceous partings; shale increases with depth.
		12 ft, clay shale, medium-dark-gray, very micaceous, noncalcareous; fair shaly to subconchoidal cleavage. Carbonaceous flakes rare. Beds of coal and coaly shale 2-8 in. thick make up approximately half the bottom 3 ft of core.
29	4, 021-4, 033	Recovered 2 ft 6 in.: Microfossils absent. Clay shale as above, but with abundant carbonized plant fragments.
----	4, 033-4, 070	Clay shale with minor siltstone.
----	4, 070-4, 077	No sample.
30	4, 077-4, 097	Recovered 18 ft: Microfossils absent.
		11 ft 4 in., sandstone, light-gray, very fine- to fine-grained, very silty and argillaceous, noncalcareous, with common carbonaceous partings dipping as much as 14°. Lower 5 ft of section slightly coarser than that above. Effective porosity at 4,078 and 4,086 ft 11.28 and 11.82 percent, respectively; rock at 4,078 ft impermeable.
		1 ft 6 in., interlaminated light-gray fine-grained sandstone and discontinuous, irregular partings of carbonaceous material; carbonaceous material decreases from about 30 percent at top to absent in basal 3 in.
		5 ft 2 in., clay shale, medium-dark-gray, noncalcareous, with rare silty laminae; poor shaly cleavage dips 3° or less.
----	4, 097-4, 100	No sample.
----	4, 100-4, 120	Clay shale with small amount of black shale in lower half.
----	4, 120-4, 130	Coal, with clay shale and some sandstone.
----	4, 130-4, 160	Clay shale with a minor black shale.
----	4, 160-4, 170	Sandstone, light-gray, very fine-grained, noncalcareous, and clay shale.
----	4, 170-4, 175	Clay shale, medium-dark-gray, and small amount siltstone.
31	4, 175-4, 193	Recovered 15 ft 6 in.: Microfossils absent.
		4 ft 7 in., siltstone, medium- to medium-light-gray, argillaceous, noncalcareous, with abundant argillaceous cross-bedded partings dipping as much as 10°.
		1 ft 9 in., coal fragments, black, shiny, with blocky fracture; badly infiltrated with drilling mud.
		2 in., claystone, medium-gray, slightly calcareous, dense.
		3 ft 4 in., clay shale, dark-gray, noncalcareous, nonmicaceous, with abundant flakes and fragments of carbonized plants. Grades into unit below.
		1 ft 4 in., siltstone, medium-gray, argillaceous, with abundant discontinuous,

Lithologic description—Continued

Core	Depth (feet)	Remarks
		argillaceous slightly carbonaceous partings. Crossbedding dips as much as 10°. A 4-in. vertical shale-filled crack, one-half inch wide, at 4,185 ft and a few shale fragments as much as 1 in. in diameter form an intraformational conglomerate at same depth.
		4 ft 4 in., clay shale, medium-dark-gray, noncalcareous, silty, with rare thin beds of siltstone; poor shaly cleavage.
----	4, 193-4, 200	No sample.
----	4, 200-4, 210	Clay shale with small amount of siltstone.
----	4, 210-4, 240	Clay shale, medium-dark-gray, with small amount of black shale and coal.
----	4, 240-4, 250	Coal and clay shale.
----	4, 250-4, 260	Coal.
----	4, 260-4, 270	Clay shale.
----	4, 270-4, 280	Siltstone with clay shale and a little coal.
----	4, 280-4, 290	Clay shale, medium-dark-gray, with some black clay shale and minor coal and siltstone.
----	4, 290-4, 300	Clay shale.
----	4, 300-4, 320	Clay shale and sandstone, light-gray, very fine-grained, slightly calcareous.
----	4, 320-4, 350	Clay shale with a little sandstone in upper part and small amount coal and black shale in lower part.
----	4, 350-4, 360	Coal with some gray clay shale and black clay shale.
----	4, 360-4, 380	Clay shale with minor coal in lower half.
----	4, 380-4, 400	No sample.
----	4, 400-4, 420	Clay shale, medium-dark-gray, noncalcareous.
----	4, 420-4, 429	Clay shale with coal and black shale.
32	4, 429-4, 439	Recovered 10 ft: Microfossils absent.
		4 ft 4 in., sandstone, light-medium-gray, very fine- to fine-grained, silty, argillaceous, noncalcareous; abundant irregular partings and thin beds of argillaceous and carbonaceous material and carbonized plant fragments.
		1 ft 4 in., interlaminated siltstone and shale, medium-gray, with laminae dipping 5°-15°.
		4 ft 4 in., clay shale, medium-dark-gray, noncalcareous, silty in upper part; grades to nonsilty claystone with conchoidal fracture at base of core.
----	4, 439-4, 490	Clay shale with streaks of coal in upper half, streaks of siltstone in lower half.
----	4, 490-4, 500	Clay shale with small amount of light-grayish-brown calcareous laminated siltstone.
----	4, 500-4, 510	Clay shale with small amount of siltstone and coal; some coal has microscopic laminae.
----	4, 510-4, 530	Clay shale, medium-dark-gray to blackish-gray, noncalcareous, with minor black shale and siltstone, medium-gray, very slightly calcareous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	4, 530-4, 540	Clay shale with black shale and minor siltstone.
----	4, 540-4, 550	Coal, shiny, black, conchoidal fracture, with small amount of clay shale.
----	4, 550-4, 560	Clay shale and coal with some black shale, siltstone and sandstone.
----	4, 560-4, 570	Claystone, medium-gray, and clay shale, with some medium-light-gray very fine-grained very silty noncalcareous sandstone, and minor calcareous siltstone.
----	4, 570-4, 580	Clay shale with small amount of siltstone.
----	4, 580-4, 600	Clay shale, with coal and siltstone and minor very fine-grained noncalcareous light-gray sandstone.
----	4, 600-4, 610	Clay shale with minor black shale. Top of Topagoruk formation at 4,600 ft.
----	4, 610-4, 620	Sandstone, light-gray, very fine-grained, very silty and argillaceous, noncalcareous; composed of angular to subangular clear and white quartz, commonly frosted, and with slight yellowish tinge to some grains. Some coal particles present, commonly in distinct laminae; dark rock fragments rare; mica, pyrite, and glauconite absent. Clay shale also present in the sample.
----	4, 620-4, 625	No sample.
33	4, 625-4, 643	Recovered 18 ft: Microfossils rare. Claystone, medium-dark-gray, slightly to very silty, micaceous, noncalcareous, with fragments of carbonized plants scattered throughout. Irregular lenticular medium-gray noncalcareous laminae of siltstone rare in upper part, increase to form approximately a third of rock below 4,638 ft; contorted bedding, probably from contemporaneous deformation, at 4,639 ft.
----	4, 643-4, 650	Clay shale and siltstone, light-olive-gray, very slightly calcareous.
----	4, 650-4, 670	Clay shale with small amount of siltstone.
----	4, 670-4, 680	Clay shale with some coal and black shale.
----	4, 680-4, 730	Clay shale with some black shale at 4,700-4,710 ft.
----	4, 730-4, 740	Clay shale with some coal.
----	4, 740-4, 760	Clay shale.
----	4, 760-4, 780	Sandstone, medium-gray, very fine- to fine-grained, calcareous; similar to that at 4,610 ft but less silty.
----	4, 780-4, 800	Clay shale with minor black shale at base.
----	4, 800-4, 804	Sandstone, light-brownish-gray, very fine-grained, very silty and argillaceous, very slightly calcareous.
34	4, 804-4, 824	Recovered 7 ft: Microfossils absent. 2 ft 4 in., interbedded medium-gray noncalcareous siltstone (two-thirds) and silty claystone (one-third), with numerous carbonaceous partings. Siltstone at 4,805 ft had faint odor of oil and gave yellow cut and yellow-brown residue in CCl ₄ .

Lithologic description—Continued

Core	Depth (feet)	Remarks
		4 in., coal, black, shaly, with platy cleavage.
		2 ft 10 in., claystone, medium-dark- to dark-gray, noncalcareous, with abundant irregular laminae and thin beds of coal and carbonaceous material.
		1 ft 6 in., claystone, medium-dark-gray, noncalcareous, with abundant carbonaceous plant fragments scattered throughout.
35	4, 824-4, 836	Recovered 12 ft: Microfossils absent. Claystone, medium-dark-gray, silty, noncalcareous, with flakes and fragments of carbonized plants scattered throughout. A few coaly laminae as much as one-eighth inch thick between 4,830 and 4,832 ft.
36	4, 836-4, 850	Recovered 14 ft: Microfossils absent. 4 ft 3 in., claystone as above. 4 ft 7 in., siltstone, light-olive-gray, very argillaceous, very slightly calcareous. Slightly coarser and sandy, with cross-bedded slightly carbonaceous partings in lower part. 2 ft 1 in., interbedded black shiny coal, with blocky to shaly cleavage and black carbonaceous noncalcareous shale. Grades into unit below.
37	4, 850-4, 864	Recovered 14 ft: Microfossils absent. 4 in., drilling mud. 6 ft 2 in., clay shale, dark-gray, noncalcareous with common fragments of carbonized plants; irregular bedding distorted in some places by thick lenses of slightly silty claystone and dark clay ironstone nodules as much as 1 in. in diameter. Grades into claystone below. 7 ft 6 in., claystone, medium-dark-gray, slightly silty, noncalcareous.
38	4, 864-4, 874	Recovered 10 ft: Microfossils absent. 3 ft 6 in., claystone as above. Grades into clay shale below. 3 ft 3 in., clay shale, medium-dark-gray, with fair shaly cleavage dipping as much as 9°; bedding distorted in top 4 in. of unit. Grades into unit below.
----	4, 874-4, 950	3 ft 3 in., clay shale, dark-gray, with common laminae of shaly coal. Clay shale, medium-dark- to dark-gray, noncalcareous, partly silty, nonmicaceous.
----	4, 950-4, 960	Clay shale and sandstone, very fine- to fine-grained, silty, argillaceous, slightly calcareous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	4, 960-4, 970	No sample.
----	4, 970-5, 040	Clay shale with small amount of siltstone at 5,010-5,030 ft. Calcite veinlet in shale fragment at 4,975 ft.
----	5, 040-5, 053	No sample.
39	5, 053-5, 073	Recovered 4 ft: Microfossils absent. Sandstone, medium-light-gray, fine-grained, very silty and argillaceous, noncalcareous, salt-and-pepper, with scattered carbonaceous laminae (dip 3°-8°) in upper part and a few patches of medium-gray clay in basal 6 in. Sand grains composed of clear and white quartz, gray chert, and dark rock and coaly particles. Impermeable sample from 5,060 ft has effective porosity of 8.7 percent.
40	5, 073-5, 087	Recovered 15 ft: Microfossils absent. Clay shale, dark-gray, finely micaceous, noncalcareous, with good to poor shaly cleavage. Thin beds of silty medium-gray claystone in top 1 ft and bottom 3 ft; a 10-in. bed of sandstone as in core 39 between 5,085 and 5,086 ft. Dip 3°.
41	5, 087-5, 100	Recovered 13 ft: Microfossils very rare. 3 in., clay shale as above. 3 ft 3 in., sandstone, as in core 39, but with abundant coaly laminae; cross bedded in part. Grades into unit below. 6 in., interlaminated medium-gray fine-grained sandstone and dark-gray clay shale. 9 ft, clay shale, dark-gray, noncalcareous, finely micaceous to nonmicaceous; shaly cleavage to conchoidal fracture.
----	5, 100-5, 110	Siltstone, medium-brownish-gray, noncalcareous, with fine coaly partings.
----	5, 110-5, 200	Clay shale with small amount of very fine-grained silty sandstone at 5,120-5,140 ft.
----	5, 200-5, 210	Clay shale and sandstone.
----	5, 210-5, 230	Clay shale with minor sandstone.
----	5, 230-5, 250	Clay shale with minor coal. Slickensides on one piece of shale.
----	5, 250-5, 281	Clay shale with minor sandstone, light-brownish-gray, very fine-grained, slightly calcareous; silty and argillaceous in lower part.
42	5, 281-5, 295	Recovered 6 ft: Microfossils absent. Clay shale as in bottom of core 41 above.
----	5, 295-5, 340	Clay shale with minor light-olive-gray slightly calcareous siltstone.
----	5, 340-5, 380	Clay shale with small amount of siltstone and minor sandstone.
----	5, 380-5, 481	Clay shale with minor siltstone, and minor sandstone at 5,440-5, 450 ft.
43	5, 481-5, 497	Recovered 14 ft: Microfossils absent. 1 ft, clay shale as in core 42 above, with

Lithologic description—Continued

Core	Depth (feet)	Remarks
		interbedded medium-gray siltstone laminae.
		13 ft, claystone, dark-gray, slightly silty, noncalcareous, with coaly plant fragments scattered throughout. Becomes slightly lighter in color and siltier toward base.
----	5, 497-5, 630	Clay shale with rare siltstone, light-brownish-gray, noncalcareous, very argillaceous, with minute patches of carbonaceous material and minor medium-light-gray very fine-grained argillaceous silty sandstone.
----	5, 630-5, 640	Clay shale with small amount of coal.
----	5, 640-5, 646	No sample.
44	5, 646-5, 660	Recovered 13 ft: Microfossils absent. 1 ft 2 in., sandstone, medium-light-gray, fine-grained, silty, argillaceous, and noncalcareous, with rare patches of clay and carbonaceous material on bedding planes. Dip 1°-3°. 11 ft. 10 in., claystone as in core 43.
----	5, 660-5, 690	Clay shale, medium-dark- to dark-gray; one piece has coaly partings; siltstone streaks at 5,660-5,670 ft.
----	5, 690-5, 700	Clay shale and minor dark-gray very argillaceous noncalcareous carbonaceous siltstone and minor medium-light-gray very fine-grained argillaceous silty slightly calcareous sandstone.
----	5, 700-5, 710	Clay shale, gray, with small amount of black clay shale.
----	5, 710-5, 720	Clay shale.
----	5, 720-5, 730	Clay shale with small amount of clay ironstone.
----	5, 730-5, 754	Clay shale with minor sandstone, very fine-grained, light-gray, calcareous.
45	5, 754-5, 772	Recovered 17 ft: Microfossils absent. 1 ft 6 in., sandstone, medium-gray, very fine-grained, very silty and argillaceous, very slightly calcareous, with scattered laminae of clay and carbonaceous material; grades into unit below. 14 ft, clay shale, dark-gray, slightly silty, slightly micaceous, noncalcareous, fair to poor shaly cleavage, some conchoidal fracture. Dip 1°-3°. 6 in., sandstone as above. 1 ft, clay shale as above.
----	5, 772-5, 927	Dark-gray clay shale, slightly silty, with scattered siltstone streaks and thin sandstone streaks at 5,820-5,840 ft.
46	5, 927-5, 942	Recovered 14 ft 6 in. Microfossils absent. Clay shale, dark-gray, partly silty, slightly to very micaceous, noncalcareous, fair to poor shaly cleavage dipping as much as 3°; coaly plant fragments scattered throughout. Pelecypod shell fragment at 5,938 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
---	5, 942-6, 030	Clay shale with minor siltstone; one piece of black carbonaceous noncalcareous clay shale with abundant subangular to subrounded white and clear very fine quartz sand scattered throughout, at 6,000-6,010 ft.
---	6, 030-6, 050	Clay shale with sandstone, light-gray, very fine-grained, argillaceous, silty, calcareous.
---	6, 050-6, 060	No sample.
---	6, 060-6, 090	Clay shale, medium-dark-gray to grayish-black.
---	6, 090-6, 100	Clay shale, with medium-light-gray fine- to very fine-grained slightly to very silty noncalcareous friable to well-consolidated sandstone.
---	6, 100-6, 110	Clay shale with sandstone, light-gray, very fine- to fine-grained, silty and argillaceous, calcareous to noncalcareous.
---	6, 110-6, 115	No sample.
47	6, 115-6, 127	No recovery.
48	6, 127-6, 138	Recovered 10 ft: Microfossils absent. Clay shale, dark-gray, partly silty, slightly to very micaceous; fair to poor shaly cleavage. Coaly plant fragments present.
---	6, 138-6, 140	No sample.
---	6, 140-6, 170	Clay shale with minor siltstone.
---	6, 170-6, 230	Clay shale.
---	6, 230-6, 250	Clay shale with small amount of siltstone.
---	6, 250-6, 320	Clay shale with streaks of sandstone at 6,270-6,300 ft.
---	6, 320-6, 330	Clay shale with light-gray very fine- to fine-grained silty argillaceous partly calcareous sandstone.
---	6, 330-6, 360	Clay shale with streaks siltstone at base.
---	6, 360-6, 367	No sample.
49	6, 367-6, 387	Recovered 12 ft: Microfossils abundant. 8 ft 6 in., clay shale as above; beds lie flat. 2 ft 6 in., sandstone, medium-gray, very fine-grained, very silty and argillaceous, very slightly calcareous; no oil odor, but a pale straw-colored cut and light-yellow residue noted in CCl ₄ . A 1-in. bed of dark-gray clay shale 2 in. below top. A 4-in. section of rock beginning 6 in. below top of sandstone contains numerous small (as much as 1 in. in diameter) irregular patches of dark-gray clay. Effective porosity at 6,383 ft 7.7 percent; rock impermeable and contains 10.5 percent carbonate minerals by weight. 1 ft, clay shale as above.
50	6, 387-6, 404	Recovered 12 ft: Microfossils absent. 10 ft, sandstone, medium-light-gray, very fine- to fine-grained, silty, argillaceous, calcareous, partly cross-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		bedded; carbonaceous laminae common at top, increasing to abundant at base; dark-gray laminae in lower part. Effective porosity 6.89 percent; carbonate minerals, 10.83 percent by weight at 6,395 ft; rock impermeable. Grades into unit below. 1 ft 10 in., siltstone, medium-gray, very argillaceous, with slightly darker laminae of clay shale and lighter laminae of siltstone. 2 in., clay shale as in core 49.
51	6, 404-6, 420	Recovered 13 ft: Microfossils absent. Clay shale, medium-dark- to dark-gray, slightly to very silty, noncalcareous, slightly micaceous; good to poor shaly cleavage. Siltstone laminae occur between 6,407 and 6,408 ft. Beds lie flat.
---	6, 420-6, 450	Clay shale.
---	6, 450-6, 460	Clay shale with sandstone.
---	6, 460-6, 530	Clay shale with rare streaks of sandstone.
---	6, 530-6, 540	Clay shale with minor siltstone.
---	6, 540-6, 580	Clay shale; small pelecypod, identified by Ralph W. Imlay as a possible Early Cretaceous <i>Aucella</i> or <i>Aucellina</i> noted at 6,550-6,560 ft.
---	6, 580-6, 591	Clay shale, dark-gray, and light-olive-gray very argillaceous siltstone. Small slickensides in carbonaceous laminae on one piece of carbonaceous siltstone.
52	6, 591-6, 599	Recovered 7 ft: Microfossils absent. 4 ft 4 in., clay shale, dark-gray, noncalcareous, with fair shaly cleavage. 7 in., siltstone, medium-dark-gray, very argillaceous, noncalcareous. 1 ft 7 in., sandstone, medium-light-gray, very fine- to fine-grained, silty, argillaceous, very to slightly calcareous, with patches and small fragments of dark-gray clay shale in upper 4 in. and in a 2-in. interval 3 in. above base. Sample from 6,595 ft had faint odor, with pale-straw-colored cut and yellow residue in CCl ₄ . Sample at 6,597 ft impermeable with effective porosity of 8.8 percent and content of carbonate minerals of 11.7 percent by weight. 6 in., clay shale as in top of core.
---	6, 599-6, 620	Clay shale with siltstone streaks.
---	6, 620-6, 630	Clay shale with some sandstone.
---	6, 630-6, 640	Clay shale.
---	6, 640-6, 690	Clay shale with very argillaceous olive-gray siltstone, which decreases from 20 percent at top to 5 percent at base.
---	6, 690-6, 700	Clay shale.
---	6, 700-6, 730	Clay shale with siltstone (partly dark-gray) decreasing from 15 to 5 percent with depth.

Lithologic description—Continued

Core	Depth (feet)	Remarks
53	6, 730-6, 737	Clay shale.
	6, 737-6, 757	Recovered 20 ft: Microfossils absent. 15 ft, sandstone, medium-light- to light-gray, fine-grained, very silty and argillaceous, calcareous, with thin beds (2-6 in. thick) of dark-gray claystone, and a few thin beds contain abundant carbonaceous laminae. Beds lie flat. Sample from 6,739 ft had faint odor, with very pale cut and very faint greasy stain in CCl ₄ ; sample from 6,749 ft had no odor, very pale-straw-colored cut, and pale-yellow greasy stain in CCl ₄ . At 6,739 ft, effective porosity 10.87 percent, and content of carbonate minerals of 10.25 percent by weight; at 6,749 ft, 9.5 and 13.34 percent, respectively, and rock is impermeable. 5 ft, claystone, medium-dark-gray, silty, slightly calcareous, with 2 in. of very fine-grained medium-light-gray calcareous sandstone at 6,755 ft, and interlaminated sandstone and dark-gray clay shale in bottom 6 in. of core.
	6, 757-6, 760	No sample.
	6, 760-6, 800	Clay shale.
	6, 800-6, 840	Clay shale with minor siltstone and streaks of sandstone at 6,800-6,810 ft.
	6, 840-6, 850	Clay shale.
	6, 850-6, 900	Clay shale with minor dark-gray siltstone.
	6, 900-6, 950	Clay shale with streaks of siltstone at 6,920-6,930 ft.
	6, 950-6, 952	No sample.
	6, 952	Total depth.

CORE ANALYSES

The effective porosity and air permeability of samples from Kaolak test well 1, shown in following table, were determined by the methods described on page 349.

HEAVY-MINERAL ANALYSIS

Heavy-mineral samples prepared in the Fairbanks laboratory by the methods described on page 349 were analyzed by Robert H. Morris, who prepared the heavy-mineral chart. (See fig. 27.) Two heavy-mineral zones are recognized in the hole: the euhedral-zircon zone, from 760 to 3,200 feet, and the zoned-zircon zone from 3,260 to 6,760 feet.

OIL AND GAS

Several slight shows of oil and gas were noted in the hole, but the gas was methane associated with the coal beds, and the oil shows consisted of slight stains in thin impermeable sandstone and siltstone beds. Two attempted formation tests, which were made with a

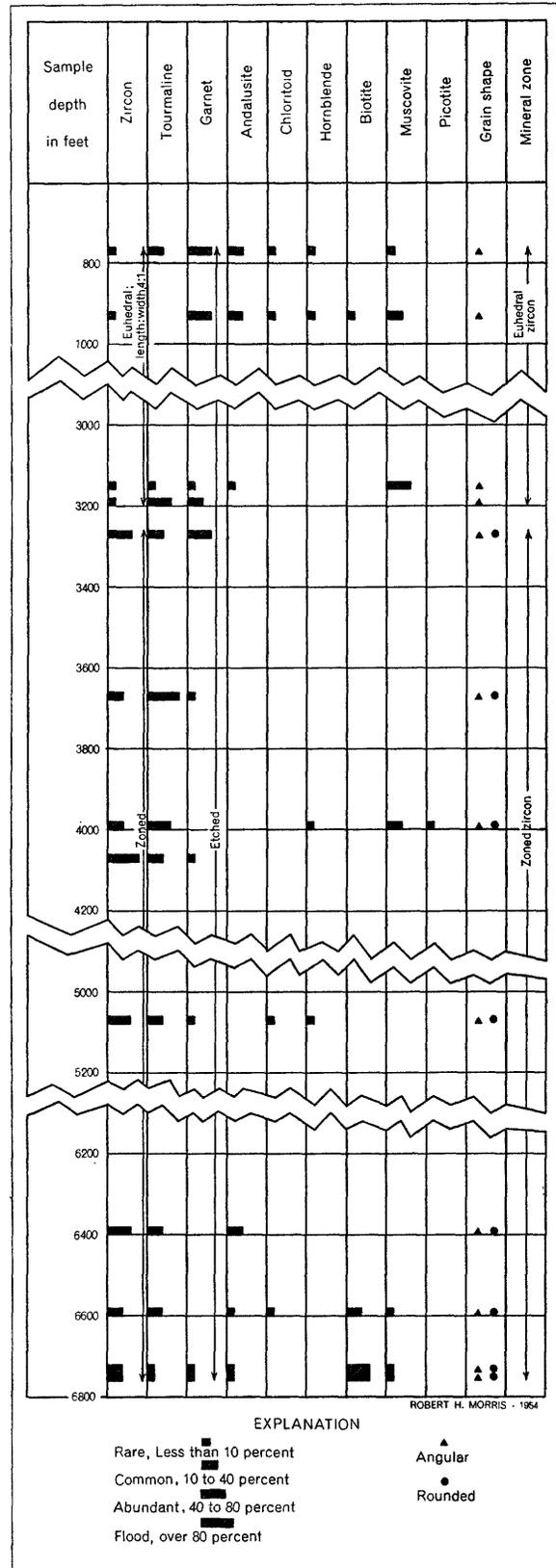


FIGURE 27.—Relative abundance of heavy minerals in Kaolak test well 1, Alaska.

Effective porosity, air permeability, and content of carbonate minerals of core samples from Kaolak test well 1

[All samples impermeable to air]

Depth (feet)	Effective porosity (percent)	Content of carbonate minerals (percent by weight)
422	12.70	
429	11.00	
937	11.55	
1,665	14.37	
1,678	11.96	
2,453	11.90	
3,158	8.33	
3,176	9.30	
3,184	9.15	
3,187	10.04	
3,191	9.50	
3,988	9.86	
4,078	11.28	
4,086 ¹	11.82	
5,060	8.70	
6,383	7.74	10.5
6,395	6.89	10.83
6,595	8.80	11.7
6,739 ¹	19.87	10.25
6,749	9.50	13.34

¹ Sample not tested for air permeability.

10½-inch wall packer at 4,799 and 4,804 feet, respectively, when the hole was at 4,874 feet, were unsuccessful because the packer failed to hold. The following table records the shows noted by the Arctic Contractors' geologist, C. W. Fleming, as well as those described in the Fairbanks laboratory.

Oil and gas shows, Kaolak test well 1

Depth (feet)	Description
Shows recorded by C. W. Fleming at rig site	
800-2,200	Slight intermittent shows of methane.
3,183	A 6-in. sandstone bed has a slight odor, slight fluorescence, and straw-colored cut.
3,191	Slight stain; good oil cut in 6-in. sandstone bed.
3,675	Bled gas.
3,985-4,033	Bled gas.
4,800-4,806	Fair stain and odor, light-straw-colored cut of oil.
4,824-4,850	Thin sandstones totaling about 9 ft has fair odor, very slight cut, no stain.
5,053-5,073	Fair odor, light-straw-colored cut, not stain, microscopic fluorescent specks.
5,085-5,086	No odor, no stain, light-straw-colored cut.
5,087-5,100	Light-brown cut, no odor, possible stain.
5,646-5,647	Very slight odor and fluorescence.
6,385-6,497	Fair odor, very slight cut, no stain.
6,595-6,598	Faint odor gas.
6,737-6,752	Slight odor, no stain, no cut.
Shows recorded by author at the Fairbanks laboratory	
3,183	No cut or residue after 2 or 3 hr in heated drying rack.
4,805	Fair odor, yellow cut, yellow-brown residue from siltstone.
6,385	No odor, pale-straw-colored cut, light-yellow residue.
6,595	Faint odor oil, pale-straw-colored cut, yellow residue.

Oil and gas shows, Kaolak test well 1—Continued

Depth (feet)	Description
6,739	Faint oil odor, very pale cut, very faint greasy stain.
6,749	No odor, very pale-straw-colored cut, pale-yellow greasy stain.

LOGISTICS

Approximately 2,000 tons of equipment was freighted overland to the site of Kaolak test well 1 in the first few months of 1951. The material was hauled in Caterpillar tractor trains over trails staked previously by scouting parties; ice bridges were made at the major river crossings. Workers were flown in by "bush" planes capable of landing on a small landing field constructed near the test hole.

The following summary of the personnel, equipment, and supplies was supplied by Arctic Contractors.

Personnel.—Supervisory personnel consisted of a drilling foreman and 2 geologists (one of whom acted as petroleum engineer); the rig crew consisted of 2 drillers, 2 derrickmen, 6 floormen, 2 firemen, 2 heavy-duty equipment mechanics, 1 roustabout, and 1 oiler, who also operated a small crane. There also were 2 cooks, 1 cook's helper, 1 electrician, 2 LVT drivers and crane operators, and 1 warehouseman-storekeeper. Temporary helpers such as carpenters, laborers, a welder, plumber, cementer, radio repairman, and Schlumberger engineer were sent to the site from Barrow as they were needed.

Housing.—Besides the rig, 2 quonsets, 8 jamesway huts, and 12 wanigans were used for housing. One quonset was used for a galley and messhall, and the other as a warehouse. The jamesway huts served as sleeping quarters, except for one used for storage. The wanigans were used to house the boiler room, geologist's office, machine shop, generator housing, a utility room, a radio room, lavatory, sleeping quarters, and rooms for cement storage, electric logging equipment, and other electrical supplies.

Vehicles and heavy equipment.—In addition to the vehicles used for transportation from Barrow, several were used during drilling operations. They included two weasels (military fully-tracked vehicles), a D8 Caterpillar tractor, a D6 Caterpillar tractor with blades, a Northwest series 25 crane, a TD-9 crane (cherry-picker), and an LVT. The drilling equipment used by Arctic contractors included—

- 1—Ideco 122-ft derrick.
- 1—National 50 drawworks, powered by 3 Caterpillar D13000 engines.
- 1—Ideco 200-ton crown block with six 30-in. sheaves.
- 1—Ideco 200-ton traveling block with four 30-in. sheaves for 1½-in. line.
- 1—National type D swivel.

- 1—Byron-Jackson hook.
- 1—Ideal rotary table.
- 1—Gardner-Denver 7¼- x 10-in. pump, powered by a Caterpillar D13000 engine.
- 1—Marlow 4-in. pump.
- 1—Kewanee 65-hp boiler.
- 1—National C-250 7¼- x 15-in. pump powered by a General Motors quad diesel engine.

Fuel, lubricant, and water consumption.—Fuel burned during drilling included 1,287 barrels of diesel fuel and 835 gallons of 72-octane gasoline. Lubricant used totaled 1,924 gallons of lubricating oil, 640 pounds of thread lubricant, and 226 pounds of grease. Water used was 489,000 gallons.

DRILLING OPERATIONS

The foundation for the rig at Kaolak test well 1 was a steel substructure mounted on piling capped with 12- by 12-inch timbers. The pump section also had a foundation of piling and 12- by 12-inch timbers, topped with heavy plank flooring. (See pl. 24B).

DRILLING NOTES

The summary of drilling operations given below was recorded primarily by Robert D. Rutledge, acting as petroleum engineer.

Notes from drill records

<i>Depth (feet)</i>	<i>Remarks</i>
113-----	Cemented 113 ft of 16½-in. welded casing with 130 sacks of Cal-Seal; the casing is jacketed to 60 ft with 22-in. casing.
1,000-----	A thousand feet of 47-pound 11¼-in. welded casing was set at 1,000 ft by pumping 32 bbl of oil and 10 bbl of brine ahead of 210 sacks of portland cement. Top of casing was then cemented with 20 sacks of Cal-Seal.
4,850-----	Pump house of the rig caught fire. Although the canvas on house burned away and wood charred, only serious damage done was to the V-belts of the large mud pump, which were burned. Drilling was delayed about 35 hr while the pump was repaired.
6,952-----	The first attempt to run the electric log was unsuccessful because the equipment would not operate; the log was made 4 days later, following repairs.

Notes from drill records—Continued

<i>Depth (feet)</i>	<i>Remarks</i>
	The well was then temporarily shut down, to wait for favorable conditions to freight 3½-inch drill pipe and other equipment to the site. While waiting, a windstorm destroyed the derrick, and it was decided to abandon the hole permanently. The hole was left full of heavy mud, with the Shaffer blowout preventers and a flow line in place. An 11¼-in. riser was screwed into the top of the blowout preventers.

DRILL AND CORE BITS

A total of 41 Reed Kor-King core bits were used to core 840 feet. Of the 41 bits, 27 were 7½-inch hard-formation (K-24) bits, and the others were 6¼-inch hard-formation bits, or soft-formation (K-25) bits of both diameters.

A total of 62 drilling bits and 3 unnumbered hole openers were used in drilling and reaming the hole. They ranged from 26 to 10½ inches in diameter, 57 of them being of the latter size. Hughes bits were most commonly used, although a few Reed, Smith, Security and Crum Brainard bits were also employed.

The footage drilled, cored, or reamed by each bit is shown on the graphic log (pl. 22) except for Hughes OSQ 10½-inch bit 31, which milled on a cone from bit 30 at 4,383 feet without deepening the hole. A 15-inch Reed reamer was used from 113 to 1,000 feet to prepare the hole for casing, but it is not shown on the log because the original hole diameter was also 15 inches. Where a drill bit was used to ream a cored interval to the normal hole width, and then continued to drill and deepen the hole, the total footage penetrated is shown on the graphic log as drilled.

DRILLING MUD

A water-base mud with Aquagel was used throughout the drilling operations. Clay and bentonite from the rock drilled aided in maintaining the desired mud characteristics, and the mud caused very little difficulty during drilling. Below about 5,500 feet, caving shale and coal caused some trouble in getting the tools in and out of the hole, until the mud weight and viscosity were increased. The following table shows the mud characteristics and the additives used in this hole.

Drilling-mud characteristics and additives, Kaolak test well 1

Depth (feet)	Weight (lb per cu ft)	Viscosity (seconds API)	Water loss (cc per 30 min)	Temperature (°F)	Aquagel (sacks)	Baroid (sacks)	Quebracho (lb)	Pyrophosphate (lb)	Driscose (lb)
110	90	75		39					
200	75	47	4.0	41					
358	74	47	5.0	46					
506	86	45.5	4.0	46			50	50	
650	81	45.5	7.0	46			10	15	
763	80	42	7.0	47			10		
828	80	45	7.5	49	2		60		20
941	82	49	4.5	75			10		
1,002	81	48.5	4.5	75	4		100	10	
1,050	83	44	4.5	73	1		30	20	
1,230	81	45	5.0	73	2		10	10	
1,380	83	45	4.0	73	2		15		
1,500	84	50	7.0	84	2		15		30
1,695	84	50	7.0	84			15		
1,800	84	46	3.5	85	2		30	30	
1,953	83	45	3.0	86	2		25		
2,060	84	48	5.0	88	1		10	5	
2,195	87	49	4.5	88	1		20		
2,290	87	52	4.0	89			10	20	
2,400	87	48	4.0	87			15	5	
2,470	83	47	3.5	88	10		10		
2,580	85	48	3.5	87			30	25	
2,795	84	46	3.5	87			15		
2,880	85	48	3.5	87			30	10	
2,945	84	48	3.5	88			20	15	
3,020	84	45	3.0	88					
3,110	84	45	3.0	88					
3,175	83	48	3.5	88					
3,240	85	48	3.0	88					
3,330	85	48	3.8	88					50
3,410	85	47	3.0	88					
3,475	84	47	3.4	88					
3,530	87	45	3.0	91					
3,610	86	46	3.4	89				30	
3,670	86	46	3.4	90				55	
3,750	85	45	4.0	90			85	90	
3,865	88	47	3.0	93			30	50	
3,910	87	47	3.5	93				25	
3,985	87	45	3.4	93					
4,020	87	43	3.5	91			20	10	
4,050	86	43	3.2	81	2				
4,100	87	43	3.8	83			20	10	
4,220	87	43	3.0	83					
4,310	87	43	3.5	85			25		
4,382	86	43	3.0	87					
4,383	88	46	3.6	87	15		50		
4,420	87	45	3.6	87			75		
4,460	88	43	3.0	91			75	15	
4,520	88	43	2.0	93				25	
4,605	89	43	2.0	93			25	15	
4,645	88	46	2.0	93			25	25	
4,730	88	45	2.5	93				50	
4,780	88	43	2.5	93				50	
4,825	88	50	2.5	89				25	
4,850	88	43	3.0	91				50	
4,870	87	48	3.0	87					
4,875	88	45	2.5	86					
4,930	86	44	3.0	81			40		
4,990	87	43	3.0	85			60		
5,050	87	43	3.0	84	5		50		
5,090	88	45	2.5	82	1		50		
5,160	88	46	2.5	85			80		
5,280	90	45	2.5	87			75	80	
5,310	90	53	2.5	89				25	
5,395	87	43	2.5	89				50	
5,470	89	46	2.5	90	3		75		
5,495	90	50	1.0	90	5		50	25	
5,550	89	46	3.0	92			25		25
5,620	89	56	3.0	92					
5,660	89	46	2.0	90					
5,705	88	46	3.0	90					
5,755	90	45	3.0	91	4		25		
5,780	89	46	3.0	93	2		25		
5,850	88	45	3.0	93			25		

Drilling-mud characteristics and additives, Kaolak test well 1—Continued

Depth (feet)	Weight (lb per cu ft)	Viscosity (seconds API)	Water loss (cc per 30 min)	Tempera- ture (°F)	Aquagel (sacks)	Baroid (sacks)	Quebracho (lb)	Pyrophos- phate (lb)	Driscose (lb)
5,900	89	45	3.0	91			25		
5,940	89	46	3.0	91			25		
5,980	89	46	3.0	91			50		
6,050	89	45	2.0	93	3		75		
6,110	90	45	2.0	93			25		
6,130	89	45	2.5	93			25		
6,160	89	45	2.0	93			25		
6,209	90	45	3.0	92			25		
6,265	89	45	2.0	93			25		
6,295	90	43	3.0	93			25		
6,370	90	43	2.0	93	3		25		
6,395	91	52	2.0	92			25		
6,425	90	49	2.0	92	25	30	150		
6,460	88	45	1.0	92	20		100		
6,530	89	49	1.0	93			50		
6,590	88	50	4.5	93			50		
6,610	90	52	4.5	93					
6,645	90	57	4.5	94					
6,720	92	70	1.0	95	40	200	100		
6,760	91	70	2.0	88			25	50	
6,805	91	60	1.0	89			25	55	
6,865	91	60	1.0	90			25	25	
6,910	91	55	1.0	90					
6,950	93	52	2.0	90	5	50		100	
Total additives					162	280	2,450	995	125

HOLE DEVIATION

Deviation measurements were made with a Totco recorder run at approximately every 200 feet. At no time was the deviation as great as 1°, the points of highest deviation being 50' at 2,940, 3,250, and 3,870 feet, and 55' at 4,150 feet. Elsewhere the deviation was commonly less than 30'; several points of no deviation were recorded. A complete list of deviation measurements is given on the graphic log (pl. 22).

ELECTRIC LOGGING

Six Schlumberger runs furnished self-potential and resistivity curves for the well from 113 to the total depth at 6,952 feet. Intervals recorded by runs 1-6, consecutively, are 113-999 feet, 1,000-1,858 feet, 1,850-2,939 feet, 2,939-4,152 feet, 4,152-4,852 feet, and 4,852-6,952 feet. All the runs were made to the current total depth of the hole except run 2 (1,000-1,858 feet), which was prevented from reaching the

bottom by mud conditions. The unlogged interval was covered by the third run. The electric log is shown on the graphic log (pl. 22). According to C. L. Mohr, Arctic Contractors' chief of exploration (written communication, Aug. 20, 1951): "The anomalies of the electric log are abnormal from 113 feet down to the approximate depth of 850 feet, probably due to the permafrost. From 850 to 980 feet the log gradually assumes a more normal aspect, and below 980 feet the effect of the permafrost cannot be recognized.

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 Sable, Edward G., 1956, New and redefined Cretaceous formations in the western part of northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, No. 11, p. 2635-2643.

MICROPALEONTOLOGIC STUDY OF MEADE TEST WELL 1 AND KAOLAK TEST WELL 1, NORTHERN ALASKA

By HARLAN R. BERGQUIST

Meade test well 1, west of Meade River, near the edge of the northern foothills, and Kaolak test well 1, on the Arctic coastal plain near the Kaolak River approximately 70 miles to the west, are the northernmost wells drilled in northern Alaska. The two wells are quite dissimilar in abundance of microfossils in the samples and in the preservation of the specimens. A correlation of the two cannot be made on the basis of fossils.

In the Meade test well an essentially unfossiliferous section (Killik tongue of the Chandler formation) of more than 1,200 feet overlies beds of the *Verneuilinoides borealis* faunal zone. In this well section the fauna is small, and specimens of each species are relatively few, but it can be matched with the *Verneuilinoides borealis* faunal zone of Early Cretaceous age in other areas to the north, east, and south. The faunal zone is extensive and can be recognized in the subsurface of much of northern Alaska; it also occurs in outcrops of the Grandstand and Tuktuk formations and the upper part of the Torok formation. A poorly developed lateral extension of this faunal zone occurs in the Corwin formation and the Kukpowruk formation in the western part of northern Alaska. Regional studies indicate that several species of Foraminifera of the *Verneuilinoides borealis* zone are the same as species from Albian beds of Europe and western Canada and that megafossils from the Grandstand, Tuktuk, and Torok formations are also Albian (Imlay, Ralph, personal communication, 1956).

In the Kaolak well, only a few Foraminifera were found, and although the species in at least the lower part of the well are part of the *Verneuilinoides borealis* fauna, the faunal zone is too poorly developed to permit correlation of the section with the formations in the Meade well or in any of the other test wells drilled in northern Alaska. The few specimens of Foraminifera in the samples from the well are so similar in preservation to specimens of like species from both the Corwin and Kukpowruk formations in the nearby Utukok River area in the extreme western part of northern Alaska that it is, in the writer's opinion, only logical to consider the well section as undifferentiated beds of the

Corwin and Kukpowruk formations. The entire section probably is also of Albian age, as suggested by the presence of the *Verneuilinoides borealis* fauna in the lower part of the well and of specimens of *Haplophragmoides topagorukensis* Tappan and *Glomospirella gaultina* (Berthelin) in the upper part. No fossils were found that suggest an age younger than Albian.

MEADE TEST WELL 1

There were no samples from the upper 40 feet of section in this well, but fossils contaminating some of the lower ditch samples from the Cretaceous section are evidence of the Gubik formation (Pleistocene) at the surface.

A section of more than 1,200 feet of essentially unfossiliferous beds in the upper part of the well is considered to be part of the nonmarine Killik tongue of the Chandler formation. From this section approximately 80 ditch and core samples were examined for microfossils, but less than a dozen specimens of Foraminifera and about an equal number of charophyte oogonia were found in them. The few charophytes were in samples from 320 feet through a depth of 1,010 feet, whereas the few specimens of Foraminifera, mostly *Verneuilinoides borealis* Tappan, were found in the lowest 200 feet of the 1,200-foot section, where the upper part of the *Verneuilinoides borealis* faunal zone is interbedded with the Killik tongue.

Verneuilinoides borealis faunal zone (1,250 feet to total depth).—The cores in the upper part of this faunal zone were barren or poorly fossiliferous, but in the ditch samples, especially below 1,420 feet, were specimens of a few of the species that are part of the *Verneuilinoides borealis* fauna and that are characteristic of the zone in other areas. Specimens of *V. borealis* were few per core sample although they occurred commonly in the ditch samples and were the only fossils in the upper 150 feet of the zone. The species was common in a ditch sample from 2,120 feet and a core sample from 3,825–3,830 feet; it was abundant at 2,720 and 2,760 feet. *Miliammina awunensis* Tappan, second in abundance, was common in samples from 1,560 feet and 3,140 feet. *Haplophragmoides topagorukensis* Tappan was

common at 2,320 feet, but in general it was found only rarely and in small numbers, mostly below 2,900 feet.

In addition to these three species, rare occurrences of a few other species of Foraminifera were as follows, in descending order of distribution: *Trochammina rainwateri* Cushman and Applin, *Psamminopelta bowsheri* Tappan, *Tritaxia manitobensis* Wickenden, *Gaudryina canadensis* Cushman, *Hyperamminoides barksdalei* Tappan, *Ammobaculites wenonahae* Tappan, *Bathysiphon vitta* Nauss, *Gaudryinella irregularis* Tappan, *Saccammina* sp., *Textularia topagorukensis* Tappan, *Involutina rotalaria* (Loeblich and Tappan), *Miliammina manitobensis* Wickenden, *Gavelinella stictata* (Tappan), *Eurycheilostoma robinsonae* Tappan, *Bathysiphon brosegi* Tappan, *Valvulineria loetterlei* Tappan, and *Lenticulina macrodisca* (Reuss). Several of these species were recently described by Mrs. Helen Tappan Loeblich (Tappan, 1957).

Calcareous Foraminifera are extremely scarce in the *Verneuilinoides borealis* zone in this well. A specimen of *Eurycheilostoma robinsonae* occurred in a ditch sample from 2,320 feet, and another was found at 2,080 feet. Specimens of *Gavelinella stictata* were found occasionally in ditch samples below 2,300 feet, and a few specimens were found in a core sample from 3,256-3,261 feet.

Specimens of *V. borealis*, *Textularia topagorukensis*, *Tritaxia manitobensis*, and *Miliammina manitobensis* occurred in core samples from 3,825-3,835 feet.

Shell fragments of *Ditrupa* sp., a worm tube, were found in a few ditch samples, the highest at 2,180 feet. Specimens of charophytes were common in a core sample from 2,365-2,375 feet.

Cores were barren from 4,114-4,185 feet and from 4,770-4,778 feet. Two questioned species of Foraminifera were found in the core from 4,457-4,463 feet. Scattered specimens of the same species that were found higher in the well occurred in ditch samples throughout the lower 1,500 feet of section. *Haplophragmoides topagorukensis* was common in a core from 5,048-5,058 feet and had associated with it a few fragments of *Ammobaculites wenonahae* Tappan. The bottom-hole core from 5,300-5,305 feet was barren.

KAOLAK TEST WELL 1

Kaolak test well 1 penetrated a section in which there were very few fossils found, and these were mostly several hundred feet apart. There were no Radiolaria nor ostracodes, and less than 100 specimens of Foraminifera were found in the 207 samples examined from this well. All the Foraminifera came from 5 cores and

21 ditch samples; 48 cores were barren. About 40 specimens occurred in 1 core sample (6,367-6,387 feet), and 25 specimens were found in samples from the 4 other fossiliferous cores (420-430 feet, 2,791-2,811 feet, 4,625-4,635 feet, and 5,087-5,100 feet). About 25 percent of all the specimens are questionably identified because of poor preservation. The species in the table below are in order of occurrence.

Species found in cores from Kaolak test well 1.

Species	Core	Highest occurrence (feet)	Total specimens in sample	Total specimens in well
<i>Haplophragmoides topagorukensis</i> Tappan	2	420-430	2	20
<i>Glomospirella gaultina</i> (Berthelin)		420-430	2	2
<i>Trochammina rutherfordi</i> Stelck and Wall		470-480	1	3
<i>Saccammina lathraei</i> Tappan	18	2,791-2,811	10	19
<i>Verneuilinoides borealis</i> Tappan		2,791-2,811	1	24
<i>Gaudryina canadensis</i> Cushman	41	5,087-5,100	1	1
<i>Bathysiphon brosegi</i> Tappan		6,160-6,170	1	1
<i>Bathysiphon vitta</i> Nauss		6,200-6,210	1	3
<i>Siphotextularia? rayi</i> Tappan		6,367-6,387	4	4
<i>Tritaxia manitobensis?</i> Wickenden	49	6,367-6,387	5	6
<i>Psamminopelta bowsheri</i> Tappan		6,367-6,387	8	8
<i>Gavelinella stictata</i> (Tappan)		6,640-6,650	1	2

The *Verneuilinoides borealis* faunal zone, the only foraminiferal zone recognized in this well, was first penetrated at 4,625 feet but is best represented by 6 species in a core from 6,367-6,387 feet. The specimens in this core constitute 42 percent of the fauna in this well. Although four lower cores were barren, it is very probable that the entire lower section is also part of the faunal zone, as a specimen of *Gavelinella stictata* occurred in a ditch sample from 6,640-6,650 feet, and another was found lower in the well. The sparse fauna is strikingly similar in species and in manner of preservation to the fauna contained in outcrop samples from both the Corwin formation and the Kukpowruk formation in western Alaska. There is, in the writer's opinion, nothing to correlate the section with formations in wells to the east. I thus consider the entire section in the well to be undifferentiated beds of the Corwin and Kukpowruk formations and to be of probable Albian age. None of the microfossils found in outcrop samples from these two formations indicate beds younger than Albian. A contact between the Corwin and Kukpowruk formations cannot be drawn in this well on the basis of fossils, as the *Verneuilinoides borealis* faunal zone occurs in both formations.

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